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LAVOISIER

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LAVOISIER.

LAVOISIER

BY

J. A. COCHRANE

B.Sc.

Illustrated

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PREFACE

It has long been a matter for surprise to me that, although Lavoisier is universally regarded as one of the outstanding figures in the history of chemistry, there is not in English any biography of him which makes any pretensions to being complete. I had hoped that an abler pen than mine would supply this deficiency and do more justice than I could possibly hope to do to a man whose scientific work ushered in a new chemical era and whose untimely death was one of the many and unforgivable acts perpetrated in the name of justice and democracy during the French Revolution. I undertook the task because I imagined that others, disappointed as I had been at the lack of a more detailed biography than can be found in books dealing with scientists and the history of science might be glad to have in English a more or less complete account of Lavoisier's life. Grimaux' biography, an invaluable book to which I am largely indebted especially for the events that led directly to Lavoisier's death, has been out of print for some time.

In regard to controversial matters, I have tried to ascertain the truth, and if at times my conclusions are not in Lavoisier's favour I hope it will not be ascribed to national prejudice. " It is not his (the biographer's) business to be complimentary; it is his business to lay bare the facts of the case as he understands them "

(Lytton Strachey). As a matter of fact, it is difficult not to be complimentary where Lavoisier is concerned. His unflagging zeal and untiring industry, apart altogether from the genius he possessed, can be fully realised only by those who have read his complete works. At the same time, his failure to give full credit to others and especially to some of his contemporaries for their work, although denied by Berthelot, Grimaux, and others, seems to be proved, and this is the one black spot in a great career all the more noticeable because of the unsullied whiteness of the background. But while this aspect of his character cannot be overlooked, it must not be unduly magnified. If he did not actually manufacture his own raw material he made such effective use of that supplied by others that the importance to chemistry of the finished product renders the source of the material of comparatively little moment. This is not to minimise the importance of Priestley's and Cavendish's discoveries; they were the essential ingredients. It means that Priestley, Cavendish, and Lavoisier must be regarded not as rivals but as collaborators.

Lavoisier was a man of many parts. Not only was he a scientist, he was a financier of no mean order; he was also educationalist, politician, social reformer, and industrialist. This rather complicates the task of his biographer. It is necessary for the sake of clearness to separate his various activities, but in doing so one is apt to lose in perspective what one gains in precision. To recount the facts of his life in strictly chronological order, which in ordinary circumstances is the method one would naturally adopt, would in this case lead only to the skein becoming hopelessly tangled. Hence I have separated the various threads and, while following one, I have where possible indicated the position of the others.

It is a strange fact that although Lavoisier was at the time of his death and for at least fifteen years before it one of the most eminent men in France, the general historian does not usually think it worth while to make any mention of him. This is only one example of the curious divorce between the history of science and general history. Science has undoubtedly changed the face of the world, and yet practically the only credit given to it by the historian is the Industrial Revolution (sometimes it is regarded as a debit), and even then the facts are not always accurate, for the steam engine is often wrongly ascribed to James Watt. No doubt the historian, having no qualifications to discuss the progress of science, feels that he had best leave it severely alone, but he can scarcely claim to trace the evolution of the modern world if he omits one of the most important factors in that evolution.

Two of my former colleagues, Mr. C. J. Mitchell. B.A., B.Sc., and Mr. W. H. Beynon, B.A., gave me some assistance in the preparation of the book, and I hereby tender them my thanks.

J. A. COCHRANE.

ST. JOHN'S,
NEWFOUNDLAND.

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LAVOISIER

CHAPTER I

INTRODUCTION

ROBERT BOYLE and Antoine Lavoisier have both been acclaimed " The Father of Modern Chemistry." To which of these eminent men is assigned the honour of this title depends on the point of view adopted by him who adjudicates between them. Sometimes the matter has been decided, consciously or unconsciously, on grounds of nationality as a result of a misguided patriotism, or rather unreasonable nationalism which is quite irrelevant to the issue. Science knows no political boundaries : the world is its parish. Genius is not a product of its environment (although a favourable environment will foster it) ; in fact, it often flourishes in spite of its environment. The scientist is a citizen of the world and his work is the heritage of all. Science is an ever-widening river which, cutting across national frontiers and being continually augmented by tributary streams of all sizes and from many sources, flows on, now placidly, now torrentially, to the sea of human knowledge. Its source is in unexplored and unexplorable antiquity and its feeders traverse all the countries of the civilised world.

To attempt to discredit a scientist simply because he is a citizen of a rival or even an enemy nation, to reject a theory not on its merits but on the ground that it was formulated by a foreigner is now happily a thing of the past, but in a milder and somewhat harmless form this parochial view is still encountered in the comparison of the achievements of scientists belonging to different countries.

The claims, therefore, of Boyle and Lavoisier to the title of " The Father of Modern Chemistry," if they can be decided at all, must be decided on grounds other than national prejudice. Boyle undoubtedly liberated chemistry from the bondage of the Aristotelian tradition and the still lingering alchemical doctrines and did much to set chemistry on the highway of progress ; and while some progress was made during the next century, it was the chemical revolution initiated by Lavoisier, his " happy co-ordination of the apparently isolated and vaguely expressed items of knowledge of his day into a harmonious and perspicuous whole " that really ushered in the modern era and from his time there has been no looking back. Such arguments, however, are fruitless. Each filled his niche in chemical history and each made real and lasting contributions to science. Which was the greater is of minor importance. It has been said that " The Sceptical Chymist " is the chemical Book of Genesis, while the " Elementary Treatise on Chemistry " is the Book of Exodus. This sums up the position admirably.

Lavoisier's life was influenced not only by the scientific but also by the social and political conditions of the period. He was involved in what has been called the most dramatic period of modern history, hence it will be necessary to take some account of the political events that led up to the Revolution and to have as a background the state of France in the middle of the eighteenth century.

In France at that time the soil was being assiduously though unconsciously prepared for the awful harvest of Revolution. The court of Louis XV was a hotbed of corruption and intrigue and the King himself was the leader in every extravagance and licentiousness. His grandfather and predecessor on the throne, the *Grand Monarque*, had had political designs which had necessitated an increased scale of war equipment and besides had maintained a court which was famed for its splendour and magnificence. Louis XV, without his predecessor's patriotism and competence, sought to imitate him, with the result that the royal financial demands increased out of all reason, and the bourgeoisie and the peasantry were oppressed by a heavy burden of taxation which was all the more onerous because the clergy and the nobility enjoyed many exemptions. The country, at least that part of it that paid taxes, was taxed far beyond its taxable capacity, and the peasants suffered severely at the hands of the agents of the hated *Ferme Générale* who stopped at nothing to extort the utmost *sol* from their miserable victims.

The peasants were practically in a state of servitude. The crown taxes and the church tithes ate up all the profits of their harvests. " They were compelled to labour for their landlords so many days in the month or year without pay, to lend them on all occasions their carts and horses, to offer them as a present certain portions of their crops, to bake their own bread at a fixed tariff in the landlord's oven, to buy their own wine at his press, with other vexations which once had been conveniences or at least due returns for service rendered. What angered the peasant with a slow, sullen, dangerous ire was that he was beginning to perceive that in exchange *no* service was rendered. His *corvée* and his *redevance* had been part of his rent and he paid the rent as well; the money and goods he expended had been in exchange for military protection, and the nobles no longer protected him, were incapable of protecting him and had no right to attempt it. For the system of government had changed while his dues and debts alone remained unchanged. In fact, he was keeping up two distinct governments; a feudal system which had long ceased to exist save in its abuses, and a centralised monarchy no less oppressive."

France was a land of "privileges and poverty." For the most part the nobles paid only occasional visits to their country manors, preferring to live a life of luxury and pleasure in Paris or other large town. Arthur Young, the agriculturist, in his "Travels in France" says: "The fields are scenes of pitiable management as the houses are of misery. . . . Heaven grant me patience while I see a country thus neglected and forgive me the oaths I swear at the absence and ignorance of the possessors."

Paris itself was a city of sharp contrasts. There were some beautiful buildings and gardens; the

Champs Elysèes was the centre of the fashionable quarter, but elsewhere the streets were narrow, crooked, and dirty. There was no footpath for pedestrians, who on the approach of my lord's carriage which careered recklessly along the streets had to protect themselves as best they could from mud and danger. The streets were the depositories of all kinds of garbage, and at night the lack of adequate illumination made them the successful haunts of those on evil bent, and the hire of a torch-bearer did not always ensure immunity from attack. The Paris of 1750 bore little resemblance to the Paris of the twentieth century.

The year 1740 saw the outbreak of the War of the Austrian Succession and this war still further impoverished the national treasury, which promptly applied another turn of the screw to the poverty-stricken peasants. It was while this war was still in progress that our story really begins.

CHAPTER II

EARLY DAYS

SUCH was that state of affairs in France when Antoine Laurent Lavoisier was born in Paris on August 26th, 1743. In the days of his childhood, however, he had no personal knowledge of poverty and distress, for he was born of parents who were blessed with a sufficiency of this world's goods. In the towns, poverty though present was not so acute as it was in the agricultural districts, thus Lavoisier did not come in contact with it in its worst forms till later in life when he began to travel.

His father, Jean Antoine Lavoisier, was an advocate and his mother was the daughter of an advocate. The family of Lavoisier was an old one, and in succeeding generations its status had gradually been raised from postman to postmaster, merchant, solicitor, and now advocate. The eldest son had always borne the Christain name Antoine, so the adoption of this name for the boy was automatic. His second Christian name, Laurent, he obtained from his grand-uncle, Laurent Waroquier, who was also his godfather. His godmother, who was later to play a large part in his youth, was his grandmother, Madame Punctis.

When the boy Lavoisier was about two years old his sister was born, and this household of four lived happily for three years until the death of the mother. The heart-broken widower with his young son and daughter went to live with his mother-in-law and his sister-in-law, the latter a young woman of twenty-two called Constance. This house had also been recently afflicted by the death of the breadwinner, and the fusion of the two families was thus a very satisfactory arrangement. The children suffered little by the death of their mother, for their aunt Constance did almost everything that a mother could have done; she lavished on them a wealth of affection and motherly care and devoted herself entirely to their upbringing. It is probable that she refused offers of marriage solely on account of her self-imposed task of being a mother to her sister's children. In later years when Lavoisier's work took him away from home for long periods, the frequent exchange of letters between him and his aunt and the sentiments expressed in these letters show that the devotion of Constance Punctis did not go unrewarded in the only manner in which such devotion can be adequately rewarded, namely by its reciprocation. And when honours began to come to Lavoisier, his aunt took the place of the proverbially proud mother and rejoiced to point out to all who would listen the uniqueness of her nephew's achievements.

The time came for young Antoine to go to school. His father's ambition was to give him the best possible education, and although he himself was not a rich man the Punctis family had ample means, and there was no difficulty in arranging the financial side of the matter. Only the best was good enough for Antoine, and in due course he went as a day scholar to the most popular, and probably the best, school in Paris, the Mazarin College. This was a school built in accordance with the wishes of Mazarin, who bequeathed two million livres for the purpose and who intended that its special functions should be the diffusion of French culture among the sons of gentlemen in the Four Nations; hence its later name—the College of the Four Nations. Surrounded by happiness and affection at home, and coming under the influence of good teachers at school, the boy developed rapidly. It was soon obvious that he had the knack of assimilating knowledge, a faculty which usually, but not always, indicates a high order of intelligence. Antoine, however, did not merely store away in his memory the information he received; he turned it over in his mind, reflected on certain points, and sometimes jotted down original thoughts and observations which, although they were probably intrinsically valueless, would have given some indication of his future career had anyone been acute enough to read the signs aright. Although naturally clever, he was not lazy; he revelled in hard mental work.

That he could talk well is shown by the fact that when he was in the class just below the highest in the school he won a prize for making an impromptu speech, the subject of which is not recorded. He also won prizes in classics. At first his bent was decidedly literary, and about this time he had ambitions in the direction of authorship. While still in his teens he planned a drama and actually wrote several scenes, but he abandoned the idea of completing it when he began to get an insight into science in his final year at school.

The Mazarin College was noted for its science course, such a course being very unusual in schools at that time. Had it not been for the chance of his being sent to this school rather than to another which offered no science course, Lavoisier might have been a successful author instead of a brilliant scientist. No doubt French literature would have gained what science would have lost, but it is difficult to imagine the history of chemistry without Lavoisier and his epoch-making work. As it turned out, science claimed him, and his literary facility is seen in the clear expositions with which he later enriched the Proceedings of the Academy of Sciences.

When Lavoisier was about seventeen years of age and still at school, the family suffered yet another loss in the death of Antoine's sister. This event served to concentrate the affection of the three adult members of the household on the boy on whom all their hopes now rested. He does not seem to have been spoilt by all the care and solicitude with which his father, his aunt, and his grandmother surrounded him, but whether this was due to his inherent strength of character or to the manner of his upbringing cannot be definitely stated. What is certain is that he was completely absorbed in his studies, so much so that any interruption irritated him. This attitude was intensified later when he was attending the university. He was loath to allow anything to come between him and his work. In order to have a good excuse for avoiding social functions he lived only on milk for several months, and in restricting himself to this diet he became so pale and ill-looking that he could reasonably plead ill-health. At this time he was only nineteen. One of his friends who was anxious about him sent him a present of some oatmeal and wrote: "Your health, my dear mathematician, is like that of all literary men whose minds are stronger than their bodies; so do not study too much and remember that a year longer in the flesh is worth more than a hundred in men's memories."

When his school life was drawing to a close a decision had to be made as to his future career. Family tradition weighed heavily as it often does, and the law claimed him as a student. He matriculated in 1763 but he did not confine himself to subjects necessary for his calling; his was to be a cultural and not a purely vocational course. On the scientific side he studied mathematics, astronomy, biology, geology, and chemistry—quite a formidable array of subjects to take on as extras! To a mind like Lavoisier's the task of assimilating all this knowledge was not really a very hard one, for the progress of science in general up to the middle of the eighteenth century had been very slow. A good teacher could give an outline of the state of the sciences in the course of a very few lectures. And Lavoisier was blessed with good teachers. In geology he had Guettard, whose fame was national, if not indeed international, and whose influence on Lavoisier was very real at this time, but more especially later when he accompanied the geologist on his scientific tours. In chemistry he sat under Rouelle, a man to whom students came from all over Europe and to whose influence chemistry owes much. He was not a great original worker, but he was a very great exponent of chemistry; he made no remarkable contribution to science, but his teaching inspired others. It may be that Rouelle, who himself occupies an insignificant niche in the history of chemistry, was really the ultimate cause of the revolution in chemical ideas which his illustrious pupil encompassed. It was Rouelle who taught Lavoisier to get his ideas and verify his facts by resort to experiment. His insistence on the experimental nature of science is shown by his having the following inscription displayed in large letters in a prominent place in his laboratory: *Nihil est in intellectu quod non prius fuerit in sensu.*

Rouelle's official position was Demonstrator in Chemistry at the *Jardin du Roi* which was at that time under the direction of Bernard de Jussieu, the botanist. Originally established by Richelieu for the study and cultivation of herbs, it had become an institution for research and for the dissemination of scientific knowledge. The Professor of Chemistry at this time was Bourdelin, the King's Physician, who delivered extremely dull lectures which, though largely attended by fashionable audiences, were listened to impatiently, for it was really Rouelle, whose duty it was to follow up each lecture with experimental demonstrations, whom they came to hear and see.

Rouelle was an eccentric man. Hoefer tells us: "He usually arrived at the lecture-room elegantly attired, velvet coat, well-powdered wig, and a little hat under his arm. Calm enough at the beginning of his lesson, he gradually warmed up to it; if his train of thought became obscure, he became impatient;

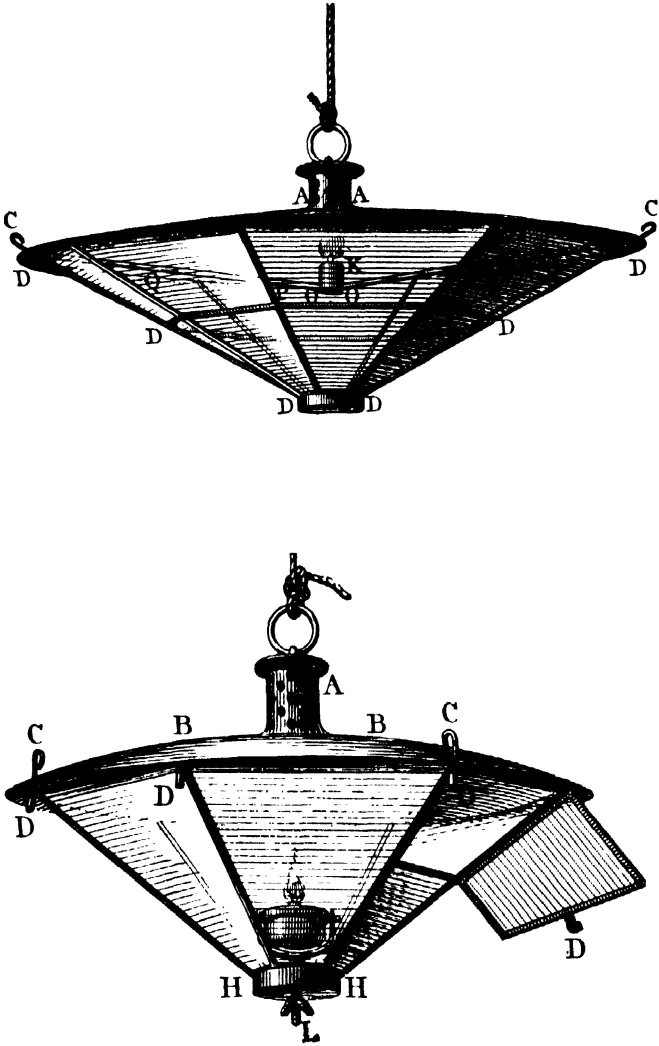
he put his hat on a piece of apparatus, took off his wig, took off his cravat, then talking all the time he unbuttoned his coat and waistcoat and discarded them one after the other. After that his ideas became clear, he became animated, he let himself go, trusting to his inspiration, and his illuminating experiments entranced his audience."

Such was Lavoisier's chemistry master, eccentric but enthusiastic, a teacher whose words were received as oracles, and whose lectures did much to popularise science.

Chemistry, however, was not yet Lavoisier's first choice as a subject for study. Mathematics and meteorology both attracted him, but especially the latter. Guericke, Pascal, and Boyle had deduced certain rough empirical rules about the relationship between the weather and atmospheric pressure, but Lavoisier was evidently dissatisfied with their conclusions and began making a series of barometric and weather observations for himself. He realised that such observations would have to be made regularly and over a wide area and for a long time. From about 1763 onwards a barometer was an essential part of the furnishings of his house and laboratory, and readings were taken every day. Even during his frequent absences from home in later life he made arrangements for the readings to be continued, and in addition he often carried a barometer with him. When he had attained to fame and fortune, he had barometers constructed and sent to some of his friends who lived in various places in France, and who were willing to send him their observations. For thirty years he collected data, but he made very little use of all this mass of information. He evidently felt that before accurate rules for forecasting the weather could be made the scale of observations would have to be very much larger than that on which he had been working. In 1790 he did actually publish a set of rules, but admitted that they were by no means complete. "The prediction of changes in the weather is an art which has principles and rules and which requires the knowledge and consideration of an experienced scientist . . . the necessary data for this art are regular daily observations of the variations of the height of the mercury in the barometer, the strength and direction of the wind at different elevations, and the hygrometric state of the air." He realised also the difficulty of obtaining barometers exactly alike, and in 1791, during a spare moment, he drew up some instructions for filling a barometer in such a way as to exclude air and moisture. He pointed out, too, that changes in temperature affected the height of the barometer.

While Rouelle's influence on Lavoisier was ultimately the most fruitful, it was Guettard the geologist with whom he came most directly into contact in his university days and those immediately following; in fact, it was probably Guettard who diverted his interest from legal into scientific channels. Just at the time when Lavoisier was one of his pupils Guettard began to consider the advisability of appointing a man to assist him in an immense task he had undertaken, the making of a geological map of France. He invited the able and enthusiastic Lavoisier to collaborate with him, and as far as can be gathered Lavoisier did not require much persuasion to abandon the law in favour of science. He immediately took up the work with the energy of youth and the ability of the seasoned worker. During the next three years he made periodical excursions with Guettard, sometimes in the immediate neighbourhood of Paris, sometimes much farther afield in search of material for the proposed map, and at the same time adding to his stock of general knowledge. Every year he took a holiday, but spent it in the study of the geology and the flora of the district in which he sojourned.

In the intervals of these excursions he carried out his first pieces of research. The first was on gypsum in 1764. He examined specimens of gypsum from different sources, and explained for the first time why plaster made from gypsum set after water had been added to it. He collected the liquid driven off by heating gypsum and tested it, showing that it was water. The setting he explained as the formation of a mass of small and irregular crystals. Already in his first research he showed those mental characteristics which were later to raise him to the front rank of chemists; in particular, he revealed that he fully appreciated the scientific attitude. Alluding to the experiments in which he showed that overburnt gypsum would not take up water of crystallisation, he said: "I could hazard some conjectures, perhaps I should even make them appear probable, but I regard such as out of place in a chemical memoir where progress must go hand in hand with experiment."

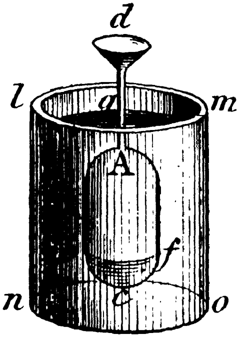


TWO OF LAVOISIER'S SUGGESTIONS FOR STREET LAMPS.

The second subject that occupied his attention in the intervals of his geological journeys was the lighting of towns. The Academy of Sciences had offered a prize for " the best method of lighting the streets of a large town at night combining brightness, ease of use, and economy." Lavoisier determined to compete and threw himself enthusiastically into the work. He began by comparing the efficiency of candles and oil-lamps, then he passed on to the question of the best shape of reflector to use and the best method of suspension of the lamp, and finally he compared wicks of different shapes and tried to determine the number and arrangement which gave the maximum efficiency. In the course of his experiments he discovered that his eyes were not sensitive enough to detect small differences in illumination, and to remedy this he lived for six weeks in a dark room, never seeing daylight. His zeal belittled the sacrifice, and his work gained in greater exactness.

The Academy divided the essays received into two classes—those which tackled the subject more or less from theoretical considerations and those which gave accounts of methods which had actually been tested. The prize was divided among three competitors who sent in essays in the second class and Lavoisier's paper, which was of the first class, was considered so good that it was decided to publish it and to award the author a gold medal, which was presented to him at a public session of the Academy on April 9th, 1766. When the essay was published it received very favourable, and in some cases enthusiastic, notices in the Press, and the general comment was that for a young man of twenty-three, Lavoisier showed remarkable promise.

In his anxiety to complete his competition essay he had to a certain extent neglected his geological work, but no sooner was the essay sent in than he resumed his work with Guettard. In June of the following year he accompanied Guettard on an extended tour in eastern France, passing through Alsace and Lorraine and going as far as Basle. Guettard's projected atlas had been officially adopted by the Government, and this expedition was undertaken under Government auspices. Lavoisier did not confine his attention to the matter in hand; he sought to improve his general knowledge whenever occasion arose. He was privileged to inspect a natural history museum at Basle, and he visited steel-works, dye-works and coal mines. Every day and sometimes several times a day he took readings of atmospheric temperature and pressure. By means of a hydrometer, made of silver to minimise danger of breakage, he found the density of the waters of the Rhine and the Seine, and of mineral and drinking water. In accordance with the main purpose of the expedition he collected samples of rocks and sent them home to Paris to await further examination. He kept a diary of the journey, in which he made copious notes about everything he saw, sometimes making his entries while on horseback. At Strasbourg he had what was for him a very pleasant experience; he came across a bookseller who had a large stock of books on chemistry, many of which were unknown in Paris. He promptly bought 500 livres worth of them, and in the course of a letter



LAVOISIER'S HYDROMETER.

to his father justified this large expenditure on the ground that he had not otherwise been extravagant.

The journey, made on horseback on account of the bad roads, lasted about four months, and was very strenuous, but young Lavoisier revelled in it. The daily companionship of the great geologist who, though of a surly disposition, seems to have treated his assistant well, was in itself a great joy to the young man. He learned from his master's experience and maturity the habit of making close observations, and he soon began to show increasing confidence in his own powers. The only thing that detracted from his happiness was the fact that he was separated from his father and his aunt (his grandmother had died the previous year). There was a frequent exchange of letters, but postal facilities in those days were meagre ; a letter took a month to reach Strasbourg from Paris. The letters from home were full of anxiety and solicitude, for the journey was not without its dangers ; highwaymen and wild beasts made travelling a hazardous affair. But the chief cause of anxiety was the proposal to visit a mine. In nearly every letter Mademoiselle Punctis referred to the dread that possessed her that some dire calamity would happen as a result of this visit. When the travellers did reach the mine they learned that it was flooded, and they had to be content with a description of it given by the officials. The premonitions of Mademoiselle Constance were thus not fulfilled.

When the homeward journey was begun it was with pleasurable anticipation that Lavoisier looked forward to the family reunion, and no less was the joy of his father and his aunt at the thought of his homecoming. His arrival was the signal for an outburst of demonstrative affection, and although he was unfeignedly glad to see his own folks again, it was characteristic of him that, greetings over, one of his first acts was to take a reading on his barometer.

Thereafter he was kept busy for some time sorting out the material collected on the expedition and rearranging his notes in more logical form, and reading the books he had purchased at Strasbourg. Some of the work he did at this time was not published till many years later, while some of it did not see the light of day till after his death. Most of the papers written about this and other journeys were descriptive of the geology, the natural history, and the scenery of the region traversed.

Thus was Lavoisier launched on his voyage of scientific discovery. Blessed with a happy home life, educated at one of the best schools in the country, and taken under the wing of the foremost scientists of the day, his career opened under the best possible auspices. These advantages, however, would have gone for naught had he not also been naturally endowed with an original and an acquisitive mind and "an infinite capacity for taking pains." His legal and business training, too, stood him in good stead when he later assumed the duties of the many offices which fell to his lot.

CHAPTER III

THE ACADEMY OF SCIENCES

THE year 1768 was a momentous one for Lavoisier, for it saw the beginning of his association with two bodies which were to influence profoundly the course of his life. The Academy of Sciences gave him incentive and encouragement in his scientific work and the *Ferme Générale* gave scope to his business interests and training and his penchant for reform. His membership of the latter organisation led to his untimely demise.

The Academy of Sciences was to France what the Royal Society was to Britain. It was founded in 1666 by Louis XIV. in rivalry to the Royal Society, and incidentally it is of interest to note that one of the founders was Mariotte, whose claim to the discovery of the law connecting the volume and the pressure of a gas is disputed by Boyle, who was one of the founders of the Royal Society. Before 1666, there were informal gatherings of men who were interested in scientific matters at the house of Père Mersenne, who corresponded with eminent men all over Europe. It was at these meetings that young Pascal, who accompanied his father to them, was infected by a love of science, and it was to Père Mersenne that Torricelli conveyed his discovery of atmospheric pressure and his invention of the barometer. This was the cradle of the Academy of Sciences. At first the King had the idea of a kind of Academy of Knowledge, with sections devoted to science, art, industry, literature, etc., and it was not till 1699 that the Academy of Sciences was established as a separate body.

In the middle of the eighteenth century the constitution of the Academy was rather complicated, inasmuch as its members were of several different grades, members of the higher grades having rights and privileges not enjoyed by those in inferior grades. There were twelve honorary members who were of the aristocracy; they alone were eligible for election as presidents and vice-presidents. Next came eighteen pensionaries, and these with the honorary members conducted the business of the Academy. Then there were twelve associates and twelve *adjoints;* these places were distributed among geometers, astronomers, mechanicians, chemists, and botanists. One function of the associates was to draw up a list of candidates for election, two members of the class in which there was a vacancy and three pensionaries forming a committee for this purpose. This list was submitted to the honorary members and the pensionaries, who elected the new member by vote. Actually it was the King who made the final choice, the decision of the Academy being only in the nature of a recommendation. The only privilege enjoyed by the *adjoints* was of attending the meetings of the Academy. If there was room they were allowed to sit beside the associates, but if not they were relegated to some back benches. In addition to these fifty-four members, there were others designated free associates, foreign associates, and veteran pensionaries and associates. Meetings were held twice a week on Wednesdays and Saturdays from three till five in the afternoon, in a room in the Louvre. Reports were read by members of work which they had been commissioned to carry out, and accounts of other research work were read by or on behalf of their authors. By application its members might receive grants toward the cost of investigations which they proposed to undertake if it was considered that such work on successful completion would materially contribute to scientific knowledge.

The Academy was a very exclusive and august body, and its doors were jealously guarded. Before a man was admitted to its membership his qualifications were carefully scrutinised and none but the most eminent gained admission to its deliberations. Membership of the Academy of Sciences was an honour of which any man might be proud, and to which no man could normally hope to attain before reaching a mature age. It was therefore a tribute to the ability and achievements of Lavoisier that his name was put on the list of candidates for election in 1766 when he was only twenty-three years of age. Doubtless Guettard was partly responsible for this unprecedented step and possibly Rouelle had strongly supported his nomination; Lalande certainly did lend his support on the ground that an energetic and talented young man like Lavoisier who, moreover, did not require to work for his living, was bound to make a very useful member. But personal recommendation would count but little beside Lavoisier's qualifications—his geological work to which Guettard could testify, and his published papers on gypsum and street lighting, both of which stamped him as a true scientist in embryo.

At the beginning of the year 1768 a vacancy among the chemists occurred, and although Lavoisier was a strong candidate, he had a rival whose claims were not inconsiderable. This was a metallurgist called Gabriel Jars, who had rendered national service in connection with lead mining. He had travelled all over Europe studying foreign methods, and from his experiences and observations he had been able to effect great improvements in the extraction of lead from its ores, and he had also learnt a method of making red lead which had till then been unknown in France. The authorities were anxious that all this work of national importance should receive some appropriate recognition, and they considered that nothing less than election to the Academy would meet the case.

The election took place on May 18th, 1768. The voting went in Lavoisier's favour with Jars second. The King, through his ministers, decided that Jars should be elected, but in order to avoid giving offence to Lavoisier's friends they created an extra and temporary place for Lavoisier. As it happened Jars died suddenly a year later, and the constitution of the Academy was automatically regularised.

This 18th of May was a red-letter day in Lavoisier's life. Congratulations poured in on him from all quarters. That a young man not yet twenty-five years of age should be admitted to the exclusive ranks of the Academy was unique, and Lavoisier's distinction was a matter of much comment. No doubt there was much shaking of hoary heads by disappointed candidates and predictions of the imminent decline of France's premier scientific society since it was now admitting schoolboys, but as it turned out the Academy in conferring so great an honour on the young scientist, added to its number one who not only enriched its proceedings by numerous important memoirs, but in time of revolutionary stress took upon himself the task of its defence.

Lavoisier came to the Academy with a reputation as a hard worker and a clear thinker, and his powers were soon tested by his colleagues. He was commissioned, usually in collaboration with one or two other members, to draw up reports on various matters which had been brought to the notice of the Academy. During the next twenty-five years the reports for which he was solely or partly responsible averaged about eight per year and included reports on such widely diverse subjects as the theory of colours, hydrometers, steam pumps, the art of the upholsterer, ink, cosmetics, steel, mesmerism, and prisons.

It is interesting to note that one of his first reports was " On a stone supposed to have fallen from the sky in a storm." He found its specific gravity; he added to it hydrochloric and sulphuric acids and obtained an effervescence in both cases. His conclusion was that it had not fallen from the sky, but that a piece of rock or ore had been struck by a thunderbolt. Whether it really was a meteor we have no means of knowing.

It is remarkable that in a body whose members were many years his senior, he should have been entrusted with such a large proportion of the investigations which it undertook. This speaks louder than any verbal eulogy. His contemporaries trusted him, and the more they trusted him the more reason he gave them for trusting him. He entered into this new sphere of work in his usual energetic way, and he was now fully and happily occupied. Between one report and the next he continued his geological work, and in a year or two after his election to the Academy he resumed his research work. All this time he was ransacking the literature of science both ancient and modern, and when he read he read critically and reflectively. Ideas which suggested themselves to him were carefully noted for future experimental verification.

Up to the age of thirty, however, Lavoisier showed only a few signs of real genius. Of mental calibre above the average he was ; in fact, one might describe him as brilliant, but after his work on gypsum and street lighting his originality seemed to lie dormant for several years until it was re-kindled to burst forth with increased intensity in connection with his epoch-making investigations on combustion.

CHAPTER IV

THE FERME GÉNÉRALE

"ALMOST immediately after Lavoisier had thus planted his foot on the ladder of fame, he set it unconsciously on the first step of the scaffold"[1] by becoming associated with a financial body which was responsible for the collection of the indirect taxes of the country. Until the year 1681 such taxes had been levied locally in the various French provinces, but in that year the system was altered so as to unify control. A company of financiers called the *Ferme Générale* was appointed which undertook to collect the taxes, including those on tobacco, salt and alcohol, as well as a levy of 2 per cent. on all merchandise imported from America. The members of this company, the *fermiers*, paid annually to the Government a sum which was fixed for a period of six years. The contract with the Government was actually made through an intermediary who, after appending his signature, immediately retired from further active participation in the affairs of the *Ferme* except to receive for his services an annual sum of 4,000 livres during the six years' period. The finance minister, in whose discretion was the appointment of these intermediaries, was in a position to do a good turn to one of his friends.

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[1] T. E. Thorpe.

The company as a whole had no administrative officials; it never even met as a company. There were several committees which dealt with the various aspects of the work, and each *fermier* was a member of two or three of the committees. The decrees of the committees were carried into effect by the "correspondents" who each had general supervision of a district.

In 1768 the number of *fermiers* was sixty, and the annual sum they paid to the Government was 90,000,000 livres. This, their capital, had to be recouped from the revenue of taxation, and the more they could squeeze from the taxpayers the greater would be their profit, but also the greater would be the sum payable to the Government for the succeeding contract. They had, of course, to bear all the expenses incurred in the collecting of the taxes and in ensuring as far as they could that the Customs and Excise regulations were carried out. The financial result of their operations was never known till the end of the six years' contract, and while profits varied considerably, 100,000 livres seems to have been not unusually high.

The *Ferme* employed thousands of men who, in many cases, abused their powers and carried out their duties with the utmost brutality. Arrests for non-payment of taxes were a daily occurrence. Smugglers who engaged in a profitable if hazardous trade received no quarter when caught. Any house was liable to be entered, forcibly if necessary, by the *Ferme's* servants in search of contraband, and the least suspicious circumstance was treated as an offence.

Suspects were regarded as guilty till proved innocent; one man, after being in prison for twenty months, was found to be guiltless of the crime of which he had been suspected. One reason for the prevalence of smuggling was the fact that prices varied enormously from province to province, due to the inequality of taxation; for example, at Angers salt was 58 livres per quintal, at Nantes it was 2. Men, women, and even children engaged in persistent attempts to outwit the officers whose vigilance, however, is shown by the large number of arrests made; in one particular year about 1,000 were arrested and 300 sent to the galleys.

Some of the members of the *Ferme* recognised that the system was being administered harshly, but they were afraid to interfere in a more than tentative manner lest their servants' ardour be cooled too much and their profits suffer unduly. It did not make matters any better from the point of view of their harassed victims that some of the *fermiers* lived extravagantly and flaunted their wealth in the faces of the down-trodden poor. On the other hand, there were honest *fermiers*, who not only deplored the state of affairs, but really made an effort to improve it. Their task, a difficult one at the best, was seriously hindered by the attitude of those who were in the *Ferme* merely for what they could get out of it.

From the point of view of the Government the system had distinct advantages in so far as it could depend on an annual revenue which was not subject to unforeseen fluctuations, and as it could transfer from its own shoulders the ever-unpopular task of tax-collecting. In other quarters, too, the system was regarded as having its satisfactory features. In 1773 it leaked out through the indiscretion of a clerk that the *Ferme's* profits were considerably reduced by the allocation of grants to a number of persons, some of whom had no part either in the work of government or in the collection of taxes. The beneficiaries included the King himself, the Dauphin, ministers, members of the Court, and even a Court singer, who was a protégé of the Queen.

Such was the organisation that Lavoisier entered in March, 1768, after he had been nominated for the Academy, but before his election. His reason for seeking admission to the *Ferme Générale* was a purely business one. His mother had left him a legacy, but this he considered insufficient to maintain freedom from financial worries, and he hoped that by investing the money in the *Ferme* he would be able to increase his capital to a figure that would ensure him a competence. Some of his friends doubted his wisdom in taking this step; they feared that the duties imposed on him by the new venture would result in the neglect or at least the curtailment of his scientific activities, and they tried to dissuade him. He did not take their advice. Negotiations resulted in his becoming *adjoint* to a *fermier* called Baudon, paying for a third interest, 520,000 livres, part of which he had to borrow. Three years later his share was increased to half.

One of his scientific friends, when he heard that Lavoisier intended joining the ranks of the financiers, jokingly remarked that at any rate the dinners he gave would be all the better. As a matter of fact, his dinners did become quite famous, and his house was for a long time the centre of the social life of a certain stratum of Parisian society. His investment turned out to be a very successful one, and the wealth he acquired freed him from the cares and worries proverbially associated with great geniuses, and also enabled him to carry out many experiments, the cost of which would have been prohibitive to any but a rich man. A contemporary said of him: " M. Lavoisier, instead of searching for the Philosophers' Stone like his brother chemists, found it in his job," but if he had not done so his efficiency as a scientist would have been impaired.

Lavoisier tried to carry out his duties as a *fermier* faithfully and honestly. After Baudon died he came into full membership, and with his increase of status he could exert a greater influence on the direction of affairs, which he used to carry certain reforms in administration leading to some simplification and therefore lower costs. He tried also to mitigate the harshness with which the operations of the *Ferme* were conducted. He took his full share in the routine work of the company, and if he did not actually earn the large profits he made, he probably came much nearer doing so than many of his fellow-financiers.

CHAPTER V

VARIED WORK. MARRIAGE

PART of the duties of a *fermier* was to undertake periodical tours of inspection in the provinces. In the same year as Lavoisier joined the company he made his first tour in this connection. He travelled through Picardy, visiting tobacco factories and toll-houses and conferring with the employees of the *Ferme*. These duties absorbed a good deal of his time, but he contrived to combine one business with another, and at the same time added to his stock of general scientific knowledge in every way possible.

It was towards the end of this year that he began his famous experiments on the alleged transmutation of water into earth. In spite of Robert Boyle's masterly analysis a century previous of Aristotle's four-element theory and his demonstration of its uselessness, the Aristotelian tradition held, and fire, air, earth and water were still regarded in many quarters as the foundations of the universe. Their mutual convertibility was also one of the basic scientific "facts." What led Lavoisier to doubt the truth of this theory we do not know; probably the conflicting opinions expressed in the books he had read led him to take up the matter for himself.

For the purpose of the experiment he used the purest natural water obtainable, rain water, and he collected it in an open space as far as was conveniently possible from the polluted atmosphere of towns. In order to ensure that the " earth " was not pre-existent in the water, he distilled the water eight times in a new alembic. He then took a vessel, called a pelican from its resemblance in shape to the symbol for self-sacrifice then and still used by sculptors, and having washed it out with the water eight times distilled, he dried and weighed it. He then poured in some of the distilled water, and, after heating the vessel to allow the bulk of the air to escape, he put on the lid and sealed it hermetically with cement and weighed it again. He placed the vessel on a tray containing some sand and heated it, maintaining the temperature between 60 and 70 degrees on the Réaumur scale (that is, not much below the boiling point) for 101 days, at the end of which time there was a white powder at the bottom of the pelican. After allowing it to cool he weighed it and found no change in weight, from which he inferred that nothing ponderable had penetrated the walls of the pelican to produce the " earth."

Having satisfied himself on that point, he emptied the pelican, dried, and weighed it, finding that it had lost 17,38 [1] grains. Did the white earth then come from the pelican? He filtered the mixture of water and white powder, dried the latter and found that it weighed only 4,9 grains, but he suspected that some remained dissolved in the water, which he confirmed by testing with a hydrometer. Accordingly, he evaporated it to dryness, and residue weighed 15,5 grains. The total weight of " earth " was therefore 20,4 grains, or 3 grains more than the weight lost by the pelican. To account for this very small extra weight Lavoisier suggested that it might have come from the vessel in which the water had been evaporated or that it might have been due to the fact that the white powder contained water of crystallisation. It did not seem to occur to him to suggest that it might have been due to experimental error.

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[1] Note the comma indicating the decimal point.

This experiment was a notable one in two respects. In the first place it shattered the two-thousand-year-old belief in the transmutation of water into earth, and secondly it showed the value of quantitative experiments. In weighing the materials used in the experiment he was following the example of Black who, while Lavoisier was still at school, has shown in his " Experiments on Magnesia Alba " that the balance could be used with good effect in the elucidation of scientific problems. Lavoisier was later to furnish further examples of the success of this method.

It is interesting to note in passing that Scheele in Sweden attacked the same problem quite independently and in a totally different manner. After heating water in a glass vessel for a considerable time, he analysed the " earth " formed and showed that it was composed of exactly the same materials as the vessel in which the water had been heated.

At the beginning of the year 1769 Lavoisier intervened in a matter that was agitating Paris. A certain engineer named Parcieux had visualised the time when the increase in the population of Paris would render the water-supply even more inadequate than it then was and had had the idea of utilising the waters of the near-by River Yvette. The water for all purposes was obtained from wells and from the Seine, and the consumption was estimated at about 6 quarts per head per day compared with the modern figure of nearly 200. It is little wonder that squalor, filth and disease abounded. Parcieux had worked out a detailed scheme which appealed to the public, but in 1768, just when it looked as if it would be adopted, he died.

Lavoisier, after examining the scheme pronounced in its favour, and when it was publicly attacked he defended it vigorously. He read a paper to the Academy on the subject, in which he demolished the arguments of its opponents, and in order that his views might reach a wider public he had his paper published in the *Mercure de France*. Ultimately, largely because of his advocacy, the scheme was adopted by the authorities, but its execution was postponed owing to lack of funds. A beginning was not made till 1788, but the Revolution put a stop to it and it was never completed.

Two days after he had read his paper to the Academy he was off again on an extended tour of inspection in connection with the *Ferme*. He went to Soissons, Lille and Reims, and included a number of smaller towns in his itinerary, the journey taking about six months. He had to send reports periodically to a " correspondent " called Paulz, and his passion for detail and thoroughness resulted in a voluminous correspondence.

On his return to Paris in January, 1770, he found more work awaiting him. He was commissioned by the Academy to make reports on several subjects, including Holland paper, invalid chairs, and the use of steam-pumps, by which the waters of the Seine could be made available for public use. The last had been put forward as an alternative to the Yvette scheme, but Lavoisier showed that it would be more costly and less efficient. He spent the greater part of April between Dieppe and Le Havre testing an instrument for measuring heights and latitudes that had been submitted to the Academy for criticism.

During the next eighteen months he made several minor reports to the Academy, but most of his time was spent in travelling on *ferme* business, traversing, this time, the Nord region and later re-visiting Reims and Soissons. He was again under the general supervision of Paulz, to whom he sent many long reports.

It was probably his close association with Paulz that led to his marriage in December, 1771. Paulz had a very high opinion of the young *adjoint* who had carried out the duties assigned to him in such an able and painstaking manner, and who had had such a rocket-like rise to fame in the scientific world. When, therefore, Paulz found himself in an awkward predicament he naturally turned to Lavoisier to help him out of it.

Paulz had a daughter called Marie Anne Pierrette, who at this time was in her fourteenth year, a pretty child with blue eyes, brown hair, and a fresh complexion. The Controller-General, the Government

Minister who had in his power the decision as to the composition of the *Ferme Générale*, had a friend, a man of fifty, who had conceived an infatuation for the girl and wanted to marry her. Naturally her father objected strongly to such a match, and at the risk of being deprived of his membership of the *ferme*, which, indeed, he was allowed to retain only at the urgent request of his fellow-members, he courteously but emphatically declined the doubtful honour of having a son-in-law nearly as old as himself and not nearly so well off. In order to put a stop to the solicitations of this undesirable suitor, Paulz decided to try to find a more suitable husband for his daughter as soon as possible. Lavoisier, by reason of his age and sound position, as well as on personal grounds, was his choice. Tall and handsome, with grey eyes and auburn hair, of an amiable disposition, a man who was in comfortable circumstances and who had already achieved a certain amount of local fame, he had all the pre-requisites of a good husband. Engrossed as he was in the multifarious duties that were now falling to him, he seems to have agreed to the proposal in a casual manner—just to oblige a friend, as it were.

The contract was signed in December in the presence of a large and fashionable gathering, which included ministers of State, Academicians, *fermiers généraux*, ladies from the court as well as relatives and friends of the betrothed. The marriage was quietly celebrated in the same month.

Lavoisier took a big risk in thus linking his life with that of a young girl who had been brought up in a convent (her mother had died when the girl was still in her infancy) and whose character was as yet unformed. The marriage might have turned out to be a tragedy, as such marriages so often do, but as it happened it was a complete success. Marie had a great respect, almost awe, for her already famous husband, and she soon began to try in a determined fashion to make herself worthy of him. In this laudable ambition she amply succeeded, so that she became in later years not only a capable and an affectionate wife, but also an accomplished assistant and amanuensis whose valuable help contributed in no small manner to her husband's success.

Although the marriage was not one of affection, neither was it arranged from motives of pecuniary gain. Paulz, although a *Fermier Générale*, lost on the first years of his contract, and while he was not exactly poor, he was not by any means a wealthy man. He gave his daughter a dot of 80,000 livres, but could make over only about a quarter of that amount at the time of the marriage. On the other hand, Lavoisier's mother had left him about 170,000 livres and his father gave him a wedding gift of 250,000 livres. The young couple thus entered on their new life in very comfortable circumstances with every prospect of freedom from financial cares.

Marriage made little difference to Lavoisier's mode of life except that for a time at least he seems to have made no lengthy journeys into the country, doubtless out of consideration for his young wife. As for the girl, she seems to have accepted her husband's devotion to his various duties without complaint, at least there is no record of conjugal quarrels. On the contrary, Lavoisier many years later testified to the tranquillity and happiness of his married life. When we remember that the bride was only fourteen years of age, a mere child, it is all the more remarkable that the venture turned out to be a felicitous one.

The year following his marriage was one of varied activity. It was in that year that the Academy received a letter the contents of which were among the oddest of the many odd pieces of information that reached the Academy from time to time. The letter told of a lad who was supposed to be able to see water through earth and rocks—a hydroscopic boy. Lavoisier, who was one of those appointed to examine the claim, treated it with scant respect; he inveighed against the credulity of some people who in an enlightened age gave credence to such obvious absurdities which had been refuted time after time. Some members wanted to have the boy brought before them so that they might put him to the test, but Lavoisier and others protested that such a procedure would lower the dignity of the Academy and make it appear as if there was really something in the claim. The matter was ultimately dropped. Not long afterwards the writer of the letter withdrew his claim, admitting that he had been hoaxed.

Curiously enough in the same year Lavoisier was privately asked to investigate another matter of a similar nature, that of the baffling phenomenon of the divining-rod. It had often been reported that certain men had the faculty of locating water, metals, and even dead bodies in the earth by the use of a twig. The Duc d'Ayen, having come across such a man, asked Macquer, one of the most eminent chemists of the day, to try to extract the man's secret or else unmask him. Macquer asked Lavoisier to cooperate with him, and together they put the man through as severe a test as they could devise. When they had satisfied themselves they reported to the Duc: " The talent of locating water is not nearly so wonderful as is commonly supposed. There is water nearly everywhere, and it is rare that a well is sunk without encountering it." And again: " As the rod sometimes turns by movements involuntary on the part of him who holds it, it is possible that some honest people have been mistaken and have attributed to an external cause an effect which depends only on themselves." The report showed that both scientists were hopelessly prejudiced. It really amounted to a confession of ignorance. The ignorance is understandable when we consider that even yet no explanation has been arrived at, but prejudice is inexcusable in a scientist unless the fact that, after all, he is human will serve as an excuse.

During the same year the Academy entrusted Lavoisier (in collaboration with others as usual) with the making of several other reports which were of no permanent interest, but his most important work, from the scientific point of view, at this time was his investigation, together with Macquer and Cadet, of the effect of heat on the diamond. The diamond had long been prized for its brilliance, and several investigators had attempted to find its composition. Boyle, Macquer and Rouelle, among others, had shown that when heated it disappeared entirely, but since the heating was carried out in open vessels no explanation of its disappearance had been forthcoming. The general opinion was that it sublimed. Lavoisier and his colleagues enclosed a diamond in an earthenware pipe and packed the pipe with charcoal. They put this into a crucible and covered it with chalk, enclosing this again in two crucibles placed mouth to mouth and luted with clay. After submitting the whole to a high temperature they found that the diamond was unchanged and concluded that the cause of its disappearance when heated in an open vessel could not be sublimation, but that it was probably a case of combustion.

The experiments with the diamond were part of a series of experiments devised with a view to finding the effect of heat on various substances apparently taken at random. Besides a charcoal furnace, several kinds of lenses were used and the experiments may have been undertaken in the first place in order to test the efficiency of the lenses as means of utilising solar heat. Lenses filled with water and with alcohol were tested, and it was decided that alcohol was better than water because it gave greater refraction, did not freeze, and no solid matter was deposited on the inside of the glass. Incidentally, one of the substances subjected to heat was red precipitate (mercuric oxide), and yet oxygen remained undiscovered for two years longer !

Later in the same year Lavoisier read another paper to the Academy in which he gave an account of some further work on the diamond. By means of a large lens he heated some small diamonds in a closed space over mercury and also over water. He reported that no water and no smoke was produced, and that when mercury was the confining liquid there was little change in the volume of the air, a slight diminution being observed when water was used. Further, he showed that the remaining " air " gave a precipitate with lime-water. The obvious conclusion was that when a diamond was heated it burned just as charcoal or sulphur did. The next deduction, that the diamond was simply another form of charcoal, could not be made till after the discovery of oxygen.

Still in the same year Lavoisier tried to work out a method of water analysis, using spirits of wine. He determined the solubilities of various substances in this liquid, finding that Glauber's salt, common salt, and Epsom salt did not dissolve to any appreciable extent, although they were soluble in water. He proposed therefore to separate such substances from mineral waters by adding spirit of wine in the proper proportions. An interesting incidental feature of this paper was his reference to the belief common among chemists that there were only two acids in the mineral kingdom—vitriolic (sulphuric) and marine (hydrochloric). Nitre, from which aqua fortis was obtained, was considered to be vegetable in origin, and phosphoric acid he also rejected as belonging to the vegetable kingdom. It is difficult to see what he gained by stressing as much as he did the distinction between mineral and vegetable acids; possibly he was merely infected with the scientist's classification bacillus.

The variety of the subjects on which the Academy was asked to give its opinion is well illustrated by the reports for which Lavoisier was partly responsible during the years 1772 to 1775. In addition to those already mentioned there were reports on the culture of rape seed, a tobacco grater, coal mining, soap, a starch factory, white lead, a fire-damper, and dyeing. In those days the Academy did not confine itself to purely academic aspects of science; it considered itself a kind of consultative body to which inventors and manufacturers might appeal for advice on technical matters.

CHAPTER VI

THE GUNPOWDER COMMITTEE

As if the *Ferme Générale* with its tours and administrative details, the Academy of Sciences with its meetings and reports, and his private investigations were not sufficient for any one man to tackle, Lavoisier undertook in 1775 in conjunction with three others the supervision of the manufacture of gunpowder for the Government. Before this date the making of gunpowder in France, like the collection of taxes, had been in the hands of a private company, the members of which had held their appointments for a period of six years. The Government could demand from this company a million pounds of gunpowder a year if they required it, but, if in times of peace a much smaller amount sufficed, the balance could not be demanded the next or any subsequent year. One result of this system was that in time of war, after the Government had received the contracted million pounds, they had to go to foreign countries to satisfy their further needs, and neutral nations, as is their wont, sold only at enhanced prices. It is said that the shortage of gunpowder was probably one of the factors that caused the termination of the Seven Years' War in 1763.

Another disadvantage of this arrangement was that the members of the company, since they held office for only six years and knew that they themselves would not reap the full benefit of any reforms they might introduce, had no incentive to improve methods of manufacture either of the gunpowder itself or of its constituents—charcoal, sulphur, and saltpetre. The result was that no progress had been made for many years. This company, too, enjoyed certain privileges which were burdensome to the country districts in which the factories were situated; for example, they were entitled to free quarters and free transport, and they had the right to dig anywhere they liked in their search for saltpetre. Farmers whose lands were thus violated had no right to compensation.

Lavoisier was asked by Turgot, the Premier, to draw up a report on the system. This he did in his usual thorough manner, and his criticisms were constructive as well as destructive. He submitted for Turgot's consideration a new plan whereby the company would be abolished and in its place would be appointed a committee of four which would be directly responsible to the Government for all the operations connected with the supply of gunpowder. Turgot liked the scheme so much that he decided to adopt it immediately in spite of the fact that the current contract had still about four years to run. He cancelled this contract and appointed four men, of whom Lavoisier was one, to serve on the committee. Lavoisier was chosen explicitly because of his eminence as a chemist (some of his work described in the next chapter had been done before this) and of the efficient and upright manner in which he had discharged his duties as a *fermier générale*.

On receiving this appointment Lavoisier took up his abode at the Arsenal, where he lived till 1791. Here he set up a laboratory, and here most of his subsequent work was carried out. This laboratory ultimately contained the latest and best instruments procurable, many of them made from Lavoisier's own specifications, and all of them paid for out of his own purse. Here, with the help of his wife and any of his friends who cared to come, he carried out his experiments on respiration, the composition of water, combustion and calcination. As his fame increased, so also did the popularity of his laboratory as a rendezvous for scientists and other interested persons. It became a recognised practice for foreign scientists to call here when they visited Paris. Among those who paid their respects were Blagden (the secretary of the Royal Society), Ingenhouz (Vienna), Fontana (Italy), Franklin (America), Jacquin (Germany), Watt and Priestley (Britain).

Among his closest friends who were at certain periods almost daily visitors were the mathematicians Lagrange, Laplace, and Monge, and the physicist Charles as well as Berthollet, the discoverer of potassium chlorate and other compounds of chlorine, Macquer and Fourcroy—the country's leading chemists. These and many other friends, including members of the nobility, counted it a privilege to be allowed to assist Lavoisier in his experiments and to be taken into his confidence with regard to his latest work. In later years he always gave a private demonstration in his laboratory and discussed his experiments with his friends before making an announcement about his theories. There is little doubt that the criticisms made at these private discussions were as helpful to Lavoisier as his demonstrations were interesting to his friends. Even non-scientific men were in attendance at the laboratory, and no doubt Lavoisier's facility in exposition was to a certain extent due to his having to explain his experiments to laymen. He encouraged young men to come to his demonstrations and even to assist him occasionally, and, because of this personal contact, he was able to recommend promising youths when his advice was asked.

The new Gunpowder Committee set to work immediately to try to increase the production of gunpowder and to ensure that the profits of its sale went to the Treasury instead of into private pockets. As a result of the improvements they initiated, production began to go up rapidly, but not rapidly enough to satisfy the men in charge of the new venture. They soon began to suspect that the methods employed were not up-to-date, and Lavoisier suggested that they should collect information about the methods used in other countries, and that they should set in train a number of experiments in their various factories. As the matter was considered urgent he thought that the best way of attaining their object would be to ask the Academy of Sciences to offer a prize for the best contribution on the subject. The actual request to the Academy came from Turgot, but it was Lavoisier who inspired it. He also helped to draw up the syllabus for the competition, and in a month it was ready for distribution. Competitors were allowed three years to prepare their theses, and meanwhile the Gunpowder Committee and the Academy both carried out some research work, most of which was done in Lavoisier's laboratory at the Arsenal. The prize was not awarded till 1782, after it had been increased in value.

Lavoisier was the executive member of the committee. He attended to all the details of administration, and was almost entirely responsible for appointing men to the senior posts in the various factories throughout the country. These posts were filled only by men of good qualifications who, before appointment, had to pass an examination in chemistry, mathematics and the construction of powder mills.

The committee soon justified the confidence which Turgot had shown in Lavoisier's scheme. In a very few years the production of gunpowder had increased to such an extent that France could now sell to other countries, and the quality had been improved so that the French powder was considered to be the best in Europe. And finally, the national revenue from this source was considerably augmented.

Lavoisier continued to serve on the committee till the troublous times of the Revolution; the events which led to his resignation will be related in a later chapter.

CHAPTER VII

THE CHEMICAL REVOLUTION

(I) THE PROBLEM OF COMBUSTION

THE crowning achievement of Lavoisier's career was undoubtedly his experimental demonstration of the oxygen theory of combustion. To appreciate fully the epoch-making nature of his work in this connection it is necessary to state briefly the position of chemistry in the middle of the eighteenth century. When Lavoisier was at school he was taught that all combustible substances and all metals were compounds which contained a common principle or element. This principle of combustibility had had many aliases, but at the moment, and for about a century previously, it had been known as phlogiston—a word introduced by the German doctor Stahl. It was supposed that when a substance burned or a metal was calcined (that is, heated strongly in air) it was decomposed, the phlogiston passing off into the air and the ash remaining. The less ash there was the nearer did the substance approach to pure phlogiston. Thus charcoal was considered to be very rich and copper deficient in phlogiston. The part played by the air in combustion and calcination was merely that of an absorbent for phlogiston.

From time to time other ideas had obtruded themselves, but they were mainly in the nature of suggestions rather than theories. Boyle, for example, had shown that a candle would not burn in a vacuum, but his theory of combustion was that the burning substance united with heat which he considered material and ponderable. Mayow had, as a result of a number of experiments, come to the conclusion that the air consisted of two different gases, only one of which supported combustion. These suggestions, however, were not taken up, and the phlogiston theory held universal sway.

This theory was quite a reasonable one up to a point and fitted a large number of the known facts. In particular, it afforded an explanation of the fact that when a calx and charcoal were heated together the metal was recovered. Obviously the charcoal, rich in phlogiston, had restored to the calx the phlogiston which the metal had lost during calcination. On the other hand, this hypothetical principle had been pressed into service to explain all chemical changes, and chemists were hard put to it to reconcile the many and varied properties assigned to it. But such was the hold of the theory that chemists did not recognise the inconsistencies into which they fell, and with equal facility and apparent conclusiveness gave, by implication, diametrically opposite properties to phlogiston. A theory is a good servant, but a bad master.

As to the nature of phlogiston itself, there were almost as many ideas as chemists. Beaumé considered it to be the matter of fire united to elementary earth, Macquer the matter of light in a fixed state, Scheele a constituent part of the matter of heat (the other part being vital air), Volta fixed air combined with matter of heat, Kirwan the basis of inflammable air.

Even apart from such confusion as to the nature of phlogiston and contradiction as to its properties, used as part of a theory of combustion, it encountered some serious difficulties, the chief of which was the admitted fact that the calx of a metal was heavier than the metal from which it was made. Many chemists took little account of changes in weight, but others who realised that this constituted a weakness of the theory, sought to bring this awkward fact into line. Boyle had suggested that the increase in weight was due to the insinuation of "fire-stuff" between the particles of the metal. Some of the phlogistians accepted this and supposed that the escape of phlogiston was more than compensated by the accession of fire particles. When the attempt was made to weigh "fire-stuff" by one of those geniuses who have a knack of taking the obvious course, and no difference was found between the weights of the same body hot and cold, the explanation had to be changed. The next suggestion—a very ingenious one—was that the elusive phlogiston was less than weightless, that is, it had negative weight; hence, a loss of phlogiston must result in an increase in weight. And there, more or less, the matter rested at the time Lavoisier took up the subject. The phlogiston theory was certainly the best theory of combustion that had been advanced, and it did fit the bulk of the known facts in a remarkable manner, even if its application to certain individual cases was subtle and not altogether convincing. It was accepted by all chemists and taught wherever chemistry was taught. Rouelle taught it, and Lavoisier was one of his pupils.

It was about 1770 that Lavoisier, having a brief respite from his exacting duties as a *fermier générale* and in an interlude between the preparation of reports for the Academy of Sciences, turned his attention to the central problem of chemistry. He was probably influenced to a certain extent by reading about the work of Black, then Professor of Chemistry in Edinburgh University, who, fifteen years earlier, had made his famous series of experiments on magnesia and limestone. Black had shown the difference between limestone and quicklime, and he had recognised " fixed air " (carbon dioxide) as a gas quite distinct from ordinary air, and, most important of all, he had demonstrated how the balance could be used to furnish a clue in the investigation of chemical changes. Up till Black's time all gases had been considered to be simply modifications of atmospheric air, and they were invariably referred to as " airs " in spite of Van Helmont's suggested adoption of the new term " gas." Black's quantitative method was adopted by Lavoisier, and to this was due his successful attack on the problem of combustion.

Lavoisier, while profiting by the experiences of his predecessors who had worked on the problem, resolved not to depend entirely on their experimental results, but to begin the investigation *de novo.* He obtained no fresh light on the subject till October, 1772, when, in the course of some experiments on sulphur and phosphorus, a new idea came to him, an idea which, still vaguely formed, must needs be thoroughly tested by experiment before being put before the scientific public. He believed he was on the right track, but with characteristic scientific caution he wanted to verify the tentative conclusions to which he had come before making any public announcement. On November 1st, 1772, he deposited with the Academy a sealed packet which contained a summary of the experiments up to date, and a memorandum in the following terms:

" About eight days ago I discovered that sulphur, far from losing weight, actually gains weight when burned; for example, from a pound of sulphur more than a pound of sulphuric acid [sulphur dioxide] is produced exclusive of atmospheric moisture. It is the same with phosphorus. This increase in weight comes from a large quantity of air which is fixed during the combustion and which is combined with the vapour.

" This discovery, which I have established by experiments which I regard as decisive, led me to think that what happens in the case of sulphur and phosphorus might also happen in the case of all substances which increase in weight either in combustion or in calcination, and I was convinced that the increase in weight in metallic calces was due to the same cause.

" Experiment has completely confirmed my conjecture; I reduced litharge in closed vessels with Hales' apparatus, and I noticed that there is liberated during the change from calx to metal a considerable quantity of air, and that the volume of this air was a thousand times greater than the quantity of litharge used. This discovery appearing to me to be the most interesting made since Stahl, I have thought it necessary to assure myself of priority in depositing this with the Secretary of the Academy to remain secret till I publish my experiments."

Here, almost at the outset of his investigations on the problem of combustion, we see Lavoisier well on the way to its solution. True, the actual advance was almost negligible in quantity, but in direction it was considerable. Two well-known facts were now correlated, the facts that the air played some part in combustion and that the burning body increased in weight. By carrying out the combustion in a closed volume of air Lavoisier had shown that part of the air disappeared, which seemed to indicate that the function of the air was that of active participant in the burning rather than that of merely a solvent for the evolved phlogiston.

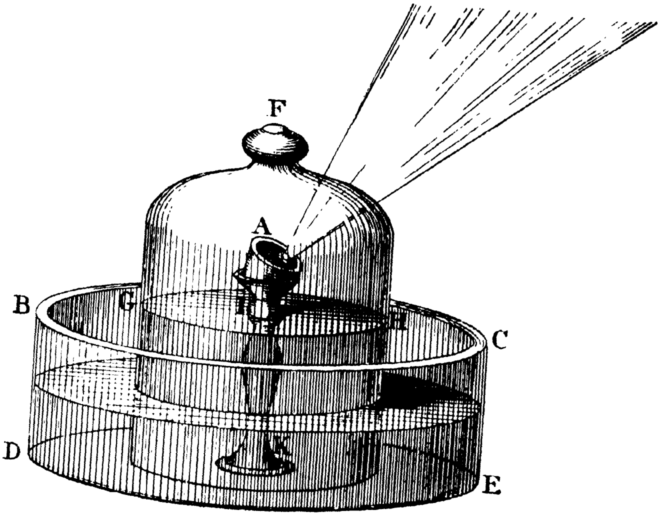
Keeping this new idea in mind he next began to repeat the experiments made by former workers in this field, but modified in such a way as to be amenable to the quantitative method of approach. He began with some experiments on " calcareous earth " and investigated the action of acids on it. This was largely a repetition of Black's work and Lavoisier's qualitative conclusions were similar to those of his contemporary. His quantitative results were not always very accurate ; for example, he gives limestone as containing only about 31½ per cent. of " fixed air," whereas it contains 44 per cent., and " fixed air " was, according to him, about a third as heavy again as air, but it is a little more than half as heavy again as air. All through this and other series of experiments his quantitative results compared very unfavourably with those of Black and particularly with those of Cavendish, and this points to the fact that he was not outstanding in the technique of experimenting. Although he often took the most minute precautions to ensure accuracy, he seldom attained the degree of accuracy one would expect.

He next went on to some experiments " On the existence of an elastic fluid fixed in metallic calces." He reduced minium and other oxides by means of charcoal in closed vessels, and he saw, by using the lime-water test recently introduced by Black, that " fixed air " was produced and that its volume was many hundreds of times that of the minium and the charcoal. For purposes of comparison he heated some charcoal alone under similar conditions and obtained only a small quantity of " fixed air." Hence the " fixed air " obviously did not come from either of the two original substances alone, but from the interaction of the two. What then was the function of the charcoal in the reduction of the calx? He says: " Is its function, as the disciples of Stahl think, to restore to the metal the phlogiston it had lost? Or does the charcoal itself enter into the composition of the elastic fluid? On this, it seems to me, the state of our knowledge does not allow us to decide." This is the first indication we have that Lavoisier was beginning to have his doubts about the phlogiston theory. How was the large quantity of " fixed air " to be accounted for by the phlogistians? According to them it was merely a case of combination of the calx and the charcoal, the latter substance being very rich in phlogiston.

He was led next to the study of the calcination of lead and tin in closed vessels, and these, with similar experiments undertaken later, led him to the following conclusions: (1) metals increased in weight during calcination; (2) the increase was not proportional to the amount of metal used; (3) the volume of the air in the vessel diminished by about one-fifth; (4) the increase in weight was very nearly equal to the weight of air which had disappeared; (5) the air remaining in the vessel was different from atmospheric air in that it would not support combustion. He carried out similar experiments with sulphur and phosphorus. At that time it was considered that phosphorus combined with water when it burned. This opinion was no doubt due to the deliquescence of the white powder formed. Lavoisier showed that dry phosphorus burned in a bell-jar over mercury just as well as it burned over water. He tried to burn phosphorus separately in a vacuum and found that it simply melted and ultimately boiled.

All this seemed to him to prove that "during burning there is combination with an elastic fluid which in becoming fixed is the cause of the increase in weight." On the other hand, his experiments seemed to point to the fact that ordinary air was not a simple substance, since only a fifth of it, and never any more, played any part in combustion and calcination.

In the course of all these experiments Lavoisier began to have a feeling that gases had a greater import-



HEATING A SUBSTANCE IN A CLOSED SPACE.

ance than had hitherto been suspected. They had been entirely overlooked by the older chemists, and it had been only recently that anyone had given more than a passing thought. Hales, in England, had done some work on gases and had devised an apparatus for collecting them—the forerunner of the pneumatic trough later improved by Priestley—and Priestley had only recently discovered "nitrous air" (nitric oxide) and "marine acid gas" (hydrogen chloride), Lavoisier went as far as to give it as his opinion that the future of chemistry was wrapped up in the study of gases and that this would probably bring about a revolution in physics and chemistry—a prophecy that was amply fulfilled.

These experiments on combustion and calcination were carried out during intervals between other duties in the years 1772 and 1773. In the latter year he began to realise that the amount of material he was accumulating was so vast that he could not hope to have it all published in the Memoirs of the Academy even if he was inclined to wait two or three years for the publication of the Memoirs. He decided to issue his results in book form, and this he did in 1774, under the title "Physical and Chemical Tracts." His intention was to follow this up by other books to be published from time to time as the number and importance of his experiments demanded, but this was never done. In the book, after a historical précis on "elastic emanations which are liberated from bodies during combustion, fermentation and effervescences," he went on to describe his own experiments and conclusions, which have been summarised above.

Lavoisier sent copies of his book to French and foreign scientists and to scientific societies in Europe and America. It caused a stir in scientific circles and called forth expressions of admiration in all quarters. Not everyone accepted his conclusions, but all praised his method of attacking the problem. Accustomed as they were to interpret all chemical phenomena in terms of phlogiston, they exhibited the habitual and proper conservatism of the scientist who, before abandoning a theory, requires overwhelming proof that the theory is erroneous or inadequate. Lavoisier's new experiments, while they had yielded results which were suggestive, did not provide a complete evidential chain. Many questions were asked by his critics. Did a part of the air really disappear during calcination and combustion, or was it merely that phlogisticated air occupied less volume than ordinary air? If a part of the air united with the metal during calcination, surely it was possible to recover it; could Lavoisier do this? He could not. This was the missing link in his chain of evidence. He tried to find this link, but it eluded him; all efforts failed to get from a calx the fifth part of the air which had disappeared. Unfortunately for Lavoisier the oxides, as we now know, are as a rule very stable bodies, and it so happened that he did not try one of the few which would have completed his proof. As a matter of fact, in 1772, when he was experimenting with burning glasses he did heat calx of mercury, but as he took no precaution on that occasion for the detection or collection of any gas that might be evolved he missed the discovery of oxygen. Scheele had isolated oxygen, but his discovery had not been published, and Bayen early in 1774 had also obtained a gas by heating mercury calx, but thought nothing more of it.

The link for which Lavoisier sought was supplied by Priestley who, however, did not know that it was a link, but regarded it merely as a matter for naive wonder. The story of his discovery is so well known that it need not be recounted in detail. Suffice it to say that on August 1st, 1774, he obtained by heating *red precipitate* (mercuric oxide) an " air " in which a candle burned very brilliantly. This " air," according to Priestley, was capable of absorbing phlogiston much more quickly and to a greater extent than ordinary air, as shown by the rapidity and the brilliance with which the candle burned in it; hence, he said, it must be singularly lacking in phlogiston, and he called it " dephlogisticated air." And there he left the matter. He attached no particular importance to his discovery; it was interesting certainly, but not more so than his recent isolation of " alkaline air " (ammonia) or " nitrous air " (nitric oxide).

The discovery, however, when it became known to the general public, caused almost as much enthusiasm and optimistic speculation as the discovery of radium at the end of last century. The most extravagant claims were made as to its possible use in curing disease and in rejuvenation, and some saw no reason why the span of life should not be considerably increased. The scientific discovery which has some spectacular features is a godsend to the journalist.

About two months after his " random experiment," Priestley, in company with his patron, the Earl of

Shelburne, visited Paris, and, as became an eminent foreign scientist many of whose discoveries had preceded him, he was hospitably entertained by his fellow-scientists in the French capital. Naturally, they " talked shop," and Priestley in his halting French told the assembled company of his August experiment. They were politely interested, but Lavoisier, who was present, pricked up his ears. Had Priestley stumbled on the fact for which he himself had been searching? After thinking the matter over he was sure that he had at last the missing link. As soon as his other duties permitted, in November, he repeated Priestley's experiment, confirmed the properties of the new " air," but, not being wedded to the phlogiston theory, being, in fact, already doubtful of its sufficiency, his interpretation of the experiment differed entirely from that of Priestley.

There are two kinds of scientific genius. There is the brilliant experimenter who discovers the facts, and there is the man who, using the facts discovered by others, collates them and establishes a generalisation or law. Priestley and Lavoisier are excellent examples of these two types. Priestley had the gift for experimenting, Lavoisier for interpreting. Few, if any of Lavoisier's experiments in the whole course of his career were entirely original; he followed up the work of others, expanded it, and gave it significance. In the case of the particular experiment under consideration, Lavoisier, having in mind his experiments on phosphorus, sulphur, lead and tin, and recalling the method by which *red precipitate* was prepared, had no doubt at all that the new gas, Priestley's dephlogisticated air, was that part of the air which had disappeared during his experiments. The calcining of mercury caused its combination with part of the air and the heating of the calx caused a decomposition into mercury and this part of the air. This, of course, was fundamentally opposed to the phlogistic explanation, which considered that mercury was a compound of the calx and phlogiston, and that the calx was a simple body.

At the Easter meeting of the Academy in 1775, Lavoisier read a paper on " The nature of the principle which combines with metals during their calcination and which increases their weight," in which he described experiments on the reduction of mercury calx by charcoal and by heat alone. The " air " produced in the latter case was not soluble in water, gave no precipitate with limewater, did not unite with fixed alkalis, did not diminish the caustic properties of caustic alkalis; metals could be calcined in it, flames burned more brightly in it, and animals could live in it. " It seems to be proved according to this," he said, " that the principle which combines with metals during their calcination and which increases their weight is nothing else than the purest part of the air which surrounds us, which we breathe, and which passes during this operation from the gaseous to the solid state."

Discussing the difference in the products when mercury calx was heated alone and with charcoal, he made the significant statement: " Since the charcoal disappears completely during the reduction of the mercury calx, and only mercury and fixed air remain at the end of the process, it follows that the principle to which the name fixed air has been given up till now results from the combination of the highly respirable part of the air with charcoal." Thus the composition of this gas was suggested, and later it was confirmed in various ways.

In this paper he made no direct attack on the phlogiston theory, but it was really the opening phase of the battle of oxygen *versus* phlogiston. He evidently preferred to let the facts speak for themselves, at least for the present.

Priestley's name is not once mentioned in the paper. Whether this was accidental or not cannot be definitely determined, but in view of similar occurrences in connection with the discovery of the composition of water it suggests that Lavoisier, not only jealous of his own claims to priority of discovery, as shown by his depositing the sealed packet with the Academy in 1772, was unwilling to acknowledge the claims of others. At any rate he failed to give credit to the part played by Priestley in the forging of his chain of evidence, and there is more than a doubt that he wished to be considered the discoverer of the gas which he afterwards called oxygen. The omission was evidently pointed out by Priestley's friends, for in 1776, in his paper on nitric acid, he admitted Priestley's claim to the discovery, but claimed priority in the conclusions drawn from the discovery—a claim which no one, and least of all Priestley, disputed. Any remaining doubt about the omission being deliberate is dissipated by another reference to the matter in 1782 in these words: "It will be remembered that at the meeting of Easter, 1775, I announced the discovery, which I had made some months before with M. Trudaine in the laboratory at Montigny, of a new kind of air up till then absolutely unknown, which we obtained by the reduction of *mercurius precipitate per se.* The air, which M. Priestley discovered at very nearly the same time as I, and I believe even before me, and which he had procured mainly from the combination of minium and of several other substances with nitrous acid, was named by him dephlogisticated air." Even now his acknowledgment of Priestley's work was grudging, and it is obvious that he wished to convey the idea that, although Priestley did happen to discover oxygen a month or two before he did, that had really nothing to do with his own work; it was a coincidence which he merely mentioned in passing. This was a very unfortunate trait in Lavoisier's character. One can hardly say whether Priestley's discovery of oxygen or its interpretation by Lavoisier was the more important, just as one cannot say that one blade of a pair of scissors cuts more than the other, but what is certain is that Lavoisier had plenty of laurels of his own without having to appropriate those of others.

This paper caused no small stir, both in the Academy and in scientific circles outside. Following, as it did only about a year after, the publication of "Physical and Chemical Tracts," and amplifying and justifying the suggestion which Lavoisier had then made, it was the cause of many a discussion. Tradition and authority were strong and were on the side of phlogiston, but reason and demonstration were also strong and were on the side of Lavoisier. It looked as if Galileo's fight against Aristotle would be waged again with different contestants and different weapons. The Academy was immediately divided into two camps, and, curiously enough, the chemists were solidly against Lavoisier; he won over the mathematicians and physicists first.

To the many attacks which were made on his novel theory, Lavoisier made no public reply for about eight years. Privately he discussed the subject with his friends, but the new ideas were so revolutionary that he dared not make a frontal attack on the old order till he had built up his case by accumulating more evidence.

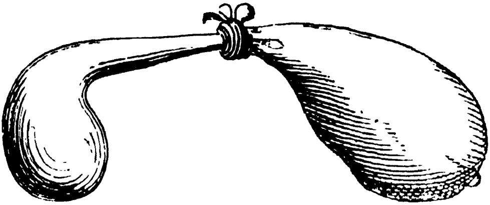
This work, however, was temporarily postponed on account of his appointment to the Gunpowder Committee which, during the first few years of its existence, took up a great deal of his time. His removal to the Arsenal, too, and the planning and furnishing of his home and his laboratory took up any spare time remaining from his other duties. About this period the increasing number of the calls upon his time necessitated his working to a time-table. To purely scientific work of a private nature he resolved to devote six hours a day—six till nine in the morning and seven till ten at night. The remainder of the day he would give to his duties in connection with the *Ferme Générale*, the Gunpowder Committee, and the meetings of the Academy. One day a week, however, he determined to devote entirely to his own scientific work. Madame Lavoisier tells us: "This was a happy day for him; some enlightened friend, some young people proud to be allowed the honour of co-operation in his experiments assembled in the laboratory in the morning; they lunched there, discussed matters, and there the theory that immortalised its author was created." It is not quite true to say that the theory was created in the laboratory at the Arsenal, but it certainly grew and gathered strength there as the evidence gradually accumulated.

Besides all this work he carried on a voluminous correspondence with friends, both at home and abroad. To Guettard he wrote about the geological atlas which was still in course of preparation; with Macquer, Beaumé, Berthollet, and Fourcroy he corresponded on scientific matters in general; to financiers and politicians he wrote on economic subjects; to members of the *Ferme Générale* and members of the Gunpowder Committee he addressed long letters on the business of their respective organisations. Periodically he received from a friend in London, Magellan (a relation of the famous explorer) copies of all scientific papers published in England. These were translated by Madame Lavoisier, who was by this time making rapid progress in her study of English, and these papers sometimes gave rise to correspondence with Black and Priestley, both of whom, as he often remarked, he held in the highest esteem.

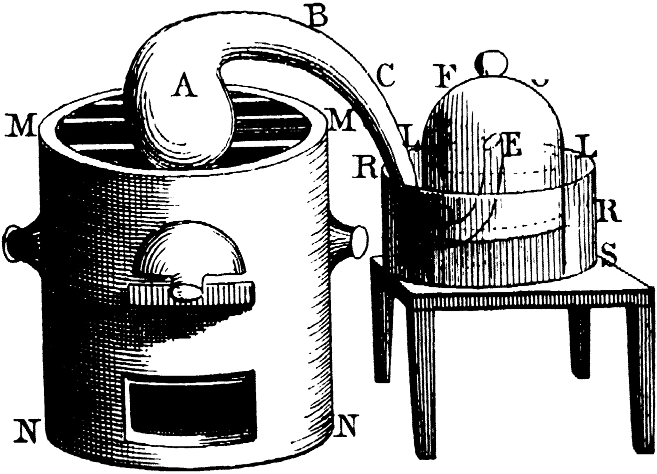
It was not until 1777 that he was able to bring to the Academy further evidence in favour of his new theory. In March of that year he described some experiments on the burning of phosphorus. He had already shown in 1772 that phosphorus gained in weight when it was burned; now he burned it (igniting it by means of a lens) under a bell-jar over mercury. The air expanded considerably at first, then diminished in volume until, when the vessel had cooled, it occupied only four-fifths or five-sixths of the jar. Only a certain definite amount of phosphorus would burn in a given quantity of air, and even fresh phosphorus introduced into the same jar would not burn. The white flakes formed were, according to him, phosphoric acid and their weight was equal to the sum of the weights of the phosphorus and the air which had disappeared. Also, on adding to the remaining air some of the gas obtained from *red precipitate*, ordinary air was re-formed.

It was in May of 1777 that Lavoisier described in a paper on respiration his crucial and well-known experiment. Actually only an outline of the experiment was given in the paper, the details being published only in 1789 in the *Elementary Treatise*. Here is his account of it:

"I took a long-necked flask with a capacity of about 36 cubic inches, and bent it so that it could be placed in a furnace with the end of the neck under a bell-jar placed in a basin of mercury. I introduced into the flask 4 ounces of pure mercury, and by means of a siphon I raised the height of the mercury in the bell-jar and carefully marked the level with a slip of gummed paper. Having carefully noted the height of the barometer and of the thermometer, I lighted a fire in the furnace and kept it up almost continuously for twelve days, so that the mercury was always very nearly at its boiling point. Nothing remarkable



THE FORERUNNER OF THE MERCURY EXPERIMENT.



happened during the first day; the mercury though not boiling was in a constant state of evaporation; small drops, at first very minute but gradually increasing in size, coated the inside of the vessel. When these had reached a certain size they dropped down again of their own accord to the bottom of the vessel. On the second day I began to see small red particles floating on the surface of the mercury; these increased in number and in bulk for four or five days and then remained in the same condition. At the end of twelve days, seeing that the calcination of the mercury proceeded no further, I extinguished the fire and let the vessel cool. Before the experiment the volume of the air enclosed in the flask and bell-jar measured about 50 cubic inches at a pressure of 28 inches and a temperature of 10 degrees. When the experiment was finished the volume was found to be not more than 42 or 43 cubic inches at the same temperature and pressure; it had suffered a reduction in volume of about one-sixth. When I collected together the red particles which had been formed and separated them as completely as possible from the liquid mercury adhering to them, I found the weight to be 45 grains. It was necessary to repeat this calcination of mercury in closed vessels several times, because it is difficult in a single operation to keep all the air which remains after the experiment, and also to collect all the red powder or mercury calx. The results of two or three experiments of the same nature will thus often be used in one account.

"The air which had been thus diminished did not cause precipitation in lime-water, but it extinguished lights, it quickly killed animals put into it, it gave scarcely any red vapours with nitrous air, nor was it perceptibly diminished by it. In short, it had been rendered completely mephitic.

"It has been proved by Dr. Priestley's experiments and also by my own that *mercurius precipitate per se* is nothing but a combination of mercury with about one-twelfth part of its weight of an air much better and more respirable—if it is permissible to use the expression—than common air. It would therefore appear to be proved that in the foregoing experiment the mercury during calcination absorbed the best and most respirable part of the air, leaving only the mephitic or non-respirable part. The following experiment still further confirmed the truth of this opinion.

"I collected carefully the 45 grains of mercury calx formed during the calcination. I put it into a very small retort, the neck of which, twice bent, was introduced into a bell-jar filled with and standing over water, and proceeded to reduce it without addition. By this operation I recovered nearly the same quantity of air as had been absorbed during the calcination, that is, about 8 to 9 cubic inches; and by recombining these 8 or 9 cubic inches with the air which had been vitiated by the calcination, I restored it to very nearly the same condition as it had been in before. In other words, I made it once more into common air. Thus restored, it no longer extinguished lights, no longer killed animals which breathed it; finally it was almost as much diminished by nitrous air as is the air of the atmosphere.

" This is the most complete kind of proof that can be accomplished in chemistry, the decomposition of the air and its recomposition, and from this it follows clearly—

" First, that five-sixths of the air which we breathe is in a mephitic condition, and is incapable of supporting the respiration of animals or the burning of substances.

" Second, that the residue, or only one-fifth, of the volume of atmospheric air is respirable.

" Third, that in the calcination of mercury the purer part of the air is absorbed and the mephitic part remains.

" Fourth, that by the union of the two parts of the air after separation into the respirable part and the mephitic part air like atmospheric air is once more formed."

This experiment formed the last essential link in Lavoisier's evidential chain. It might not be a very strong chain, but at any rate it was complete and further strengthening links were soon to be forged.

Lavoisier's attention was drawn to the subject of respiration by a paper which Priestley had read before the Royal Society the previous year. The English chemist had shown that the air in a closed vessel which had been "rendered noxious" either by burning a candle in it or by placing a living animal in it could be made fit for burning or breathing again by putting in it a sprig of mint or some other green vegetable matter. He had concluded that burning or breathing phlogisticated the air and that the green leaves re-absorbed the phlogiston and so caused it to regain its former state. He had attributed this action to the presence of the green colouring matter in the leaves and to sunlight, and he had suggested that this was nature's way of keeping the air fit for breathing. The fact that Priestley had shown that burning and breathing were akin naturally interested Lavoisier at this particular time, and he decided to carry out some investigations on respiration in the expectation that it would bring some more grist to the mill of his new theory.

One of his first experiments began by confining a white mouse in a bell-jar full of air and standing over mercury. It died in fifty-five minutes and there was a decrease of about one-sixtieth in the volume of the air. The remaining gas gave a precipitate with lime-water and extinguished flames; a bird introduced into it died in a few moments. It therefore resembled the air left after the calcination of mercury in that it did not support life or the combustion of a candle, but differed in giving a precipitate with lime-water. Apart from this, however, the diminution of the air was very much smaller in this case.

He next introduced some caustic alkali into a vessel into which he had passed some "air vitiated by respiration," which caused a diminution in the volume of the air of nearly one-sixth, and at the same time the alkali lost its causticity. This left no doubt about the presence of a considerable quantity of fixed air which Lavoisier now began to call "chalky acid." The other part which was not absorbed by the alkali was by all the tests he applied identical with the air remaining after the calcination of mercury and could be restored to " its ordinary and respirable condition " by mixing it with about a quarter of its volume of " highly respirable air " obtained by heating mercury calx. Hence he concluded that in respiration " vital air " was abstracted from ordinary air and an almost equal volume of " chalky acid " was added to it. He was not sure of the mechanism of the change which, of course, was really a physiological and not a chemical problem; either the " vital air " was changed into " fixed air," in the lungs or the lungs absorbed the " vital air," while at the same time the " fixed air " formed elsewhere in the body and carried to the lungs was given out. In support of the latter alternative he adduced analogies between the red colour of the calces of mercury, iron, and lead on the one hand, and the red colour of the blood on the other, but fortunately for his reputation, he did not stress the point, although he did mention the fact that " Dr. Priestley in particular has shown that blood is red only as long as it is continually in contact with the atmosphere or its more respirable part; that it becomes dark in chalky acid, in nitrous air, in inflammable air, in fact, in all airs which cannot be breathed as well as in the exhausted receiver of an air-pump." In favour of the other alternative, he recalled the fact proved two years earlier that " vital air " can be changed into " fixed air " by means of powdered charcoal.

In another paper read to the Academy in the same year he described some experiments on the combustion of a candle and showed that the results were very similar to those obtained in the experiments on respiration. His method of lighting the candle, which was placed in a bell-jar over mercury, is very interesting. He put a tiny piece of phosphorus at the base of the wick, then after heating one end of a bent wire he quickly pushed this end through the mercury, and touched the phosphorus with it. He burned a candle in ordinary air and also in " highly respirable air," but found little diminution in volume until after the introduction of caustic alkali. This experiment seemed to him to show that the air was not phlogisticated by burning, and that the so-called phlogisticated air was really part of ordinary air which took no part in the process of combustion.

Still in the same year (a year of great activity this) he gave his views on the formation of vapours from volatile liquids. After recalling some well-known facts, for example, the boiling of ether under reduced pressure, he went on: " From all these facts I conclude that every vapour, every air, and in general every aeriform elastic fluid is a combination of fire matter with a fluid or even with a volatile solid body; that volatility is nothing else than the property which bodies have of dissolving in some way, of combining with the igneous fluid and of forming with it aeriform fluids." Here we have Lavoisier declaring his adherence to the current idea of fire-matter, but with this difference that he considered it to be imponderable. The tradition that fire was an element handed down from Greek times proved to be even harder to eradicate than in the case of any of the other three. Lavoisier held the theory of a weightless caloric all his life. It is rather curious that while he was condemning the hypothetical phlogiston he should be adding the weight of his authority to an equally undemonstrable caloric, and, as we shall see presently, this was an essential part of the new theory which he set in opposition to the phlogiston theory, a part which is often omitted in dealing with his chemical work. He considered every gas to be a compound of caloric and a " base." When the gas entered into combination as in the formation of a solid calx, the " base " united with the metal and the caloric was liberated.

Having reached this point in his investigation of the problem of combustion, Lavoisier considered that he was now in a position to formulate definitely and explicitly his new theory of combustion, calcination, and respiration, and this he did in a paper entitled " On Combustion in General " in 1777. In this paper he proposed " a new theory of combustion, or rather, to speak with the reserve I have always imposed upon myself, a hypothesis by whose help can be explained all the phenomena of combustion, of calcination, and even in part those which accompany the respiration of animals." Even now, with much more evidence at his disposal, he put forward his suggestions as a theory not rigorously demonstrated, but as a hypothesis that seemed to be very probable, and that must yet undergo other tests before being generally accepted. He referred to the experiments described in " Physical and Chemical Tracts " and subsequent papers, and submitted that the experiments which he had carried out furnished a very strong probability that combustion and calcination, instead of being decompositions as the phlogiston theory necessitated, were, on the contrary, combinations. His theory accounted very satisfactorily for the increase in weight on combustion and calcination and also for the decrease in the volume of the air when these processes were carried out in closed vessels. Why then introduce a hypothetical phlogiston to explain phenomena which could be fully explained without its help? Did combustible bodies contain phlogiston because they burned, or did they burn because they contained phlogiston? What was phlogiston?

Still there was difference of opinion: the sceptical chemists were by no means convinced by Lavoisier's plausible arguments. In the light of modern knowledge it is difficult for us to appreciate the reasons for the opposition to the new theory. Combustion and calcination seem to us to be among the simplest of chemical changes; in fact, the beginner is introduced to chemistry by the experimental study of such changes. Yet there was something to be said for Lavoisier's opponents. If a similar situation arose in modern times what would be the attitude of scientists? If a young man in his early thirties announced at one of the annual meetings of the British Association some theory which was entirely contrary to accepted ideas of the subject he would create a sensation, but no matter how convincing he might sound we should feel that there was a catch in it somewhere, and certainly judgment would be suspended until the evidence had been thoroughly examined. Such a situation has actually arisen within recent years in connection with Einstein's Relativity Theory, and acceptance by those qualified to pass judgment came only after rigorous examination.

In 1777 the position was that in some quarters judgment was suspended, while in others opposition was active. A few, chiefly those in Lavoisier's inner circle of friends, voted whole-heartedly for the new ideas. Both in France and in foreign countries objections were raised either on the ground of the inadequacy of the theory, or on the ground of its superfluity. Lavoisier was not at all perturbed by the opposition ; in fact, he expected it, and he was in no hurry to respond to the many criticisms which were aimed at him. He let his opponents have their say and, as time permitted, endeavoured to accumulate fresh evidence. As it happened, it was one of his most illustrious critics and not he himself who provided the strongest piece of evidence, but this must be reserved for the next chapter.

Another important announcement to the Academy in this fruitful year, 1777, was contained in a paper entitled " On the Nature of Acids." Its central idea had already been suggested in " Combustion in General," for there he had drawn the conclusion that a combustible body was, as a rule, changed into an acid and a metal into a calx by its combination with " highly respirable air." It was this point that he now developed into his oxygen theory of acids. He pointed out that phosphoric acid consisted of phosphorus and " vital air," vitriolic acid of sulphur and " vital air," carbonic acid (as he now called it) of carbon and " vital air," nitrous acid of " saltpetre gas " (nitric oxide) and " vital air." Hence, he said, because all acids contain " vital air," this must be the acidifying principle. " It is seen that vital air is a principle common to all, and that it is this that constitutes their acidity ; that they are further differentiated from one another by the nature of the substance acidified. In every acid we have to distinguish between the acidifiable base to which M. de Morveau has given the name radical and the acidifying principle, that is, vital air." He proposed to call this acidifying principle the oxygen principle (principe oxygène) which he later shortened to oxygen (oxygène). But this was not the gas we call oxygen ; it was " highly respirable air in a state of fixity," and when the gas was " fixed " during combustion it was decomposed, caloric being liberated. He stated very explicitly that " vital air " was composed of " principe oxygène " united to fire-matter or caloric. When phosphorus, sulphur, or carbon burned it united with the oxygen principle, and the caloric was set free. Marine (hydrochloric) acid, of course, proved a stumbling block to Lavoisier, but since its composition was not known, the obvious thing to do was to assume that it was the oxygen compound of an unknown element or radical. Lavoisier did not discuss the fact that although calces contained oxygen, the acidifying principle, yet they had no acidic properties, and this was one of the weaknesses of the theory. It was not sufficient to say that the combustion of non-metals produced acids, but the calcination of metals resulted in calces.

Lavoisier had the utmost confidence in his theory. In 1787 he wrote : " . . . the theory of acidification if indeed the term theory can be applied to a truth or fact of observation which by its universality can be regarded as a fixed law of nature. We have not yet succeeded in decomposing and recomposing all acids, but at least we are sure that oxygen is a principle common and necessary for the formation of all of them whose composition we know." Followed some examples, then: "Up to this point the new doctrine of acidification is obviously only an exposition of a fact; but when from these particular facts the general conclusion is drawn that oxygen is a principle common to all acids, the conclusion is determined by analogy, and it is here that theory begins; but experiments which are being multiplied every day give it a greater and greater probability, and we believe that this is not the least important part of the new doctrine."

The two years succeeding 1777 were occupied mainly with matters other than scientific, but during the winter of 1779–1780 he and Laplace undertook their famous investigations on heat. Using their ice calorimeter, they measured specific heats and heats of combustion, and from the heat of formation of carbon dioxide they were led to the subject of respiration. A guinea-pig was confined under a bell-jar and kept supplied with oxygen. The carbon dioxide produced in ten hours was measured, and they concluded that the changing of pure air into fixed air was the cause of animal heat and finally that "respiration is therefore a combustion, very slow certainly, but perfectly similar to that of carbon."

Until 1783, when Cavendish discovered the composition of water, very little additional evidence for Lavoisier's new theory was forthcoming. Discussion continued, but the new ideas made no headway. It will be noticed that so far Lavoisier had made no direct attack on phlogiston in any of his papers; he had been more concerned to build up his own theory than to destroy Stahl's. In 1782, however, in the course of a paper entitled " On the Solution of Metals in Acids," he did make a slighting reference to it. " This idea," he said, " introduced into chemistry by Stahl, far from having illumined it seems to me to have made of it an obscure and unintelligible science for those who have not made a very close study of it; it is the *deus ex machina* of the metaphysician; a theory that explains everything and explains nothing, to which, in turn, opposite qualities are ascribed."

In 1783, in his " Reflexions on Phlogiston," he examined Stahl's theory and expounded his own with a greater confidence then he had yet shown. While giving Stahl the credit for recognising that combustion and calcination are chemically similar, and that combustibility could be transferred (as in the reduction of a calx by carbon), he asked his readers to forget that theory and to try to approach the problem with unbiassed minds in the light of recent experiments.

He then tore the phlogiston theory ruthlessly to pieces. His indictment was exhausting and trenchant. Among the many telling points he made, he asked why calces were not reduced by phlogisticated air, and how it was that when mercury was calcined in oxygen *all* the oxygen was used and nothing else remained. He summed up his whole argument very neatly in the following way: " Chemists have made of phlogiston a vague principle which is not rigorously defined and which consequently can be adapted to any explanation for which it is required. Sometimes this principle is heavy, sometimes it is not; sometimes it is free fire, sometimes it is fire combined with an earthy element; sometimes it passes through the pores of vessels, sometimes they are impenetrable to it; it explains at the same time causticity and non-causticity, transparency and opacity, colour and the absence of colour. It is a veritable Proteus which changes its form at every moment."

He then recapitulated the main points of his own theory. He pointed out that it was necessary to distinguish between fact and hypothesis, but although he reiterated this again and again, he himself did not always keep the distinction in mind; he rejected the hypothetical phlogiston, but retained the equally hypothetical caloric and, in fact, embodied it in his theory as one of its essential " facts."

With this paper ends the first phase of the battle of oxygen *versus* phlogiston. The adversaries had come to grips, but the phlogistians had so far held their ground, chiefly owing to their entrenchments of tradition. The enemy, however, their lack of numbers compensated by the superiority of their munitions, were insistently challenging the established stronghold, and the issue was never really in doubt. Tradition and authority may hold out for a time, but unless they can survive the onslaughts of experiment and reason, they cannot continue indefinitely to command allegiance. The doom of phlogiston was sealed by the advent from an unexpected quarter of a powerful ally who placed at Lavoisier's disposal a new weapon. Curiously enough, the new ally was a phlogistian, one of the staunchest and most loyal of them, and he did not realise that the new weapon he invented was a weapon, and still less that it would be used with deadly effect by the oxygenists.

CHAPTER VIII

THE CHEMICAL REVOLUTION

(2) THE COMPOSITION OF WATER

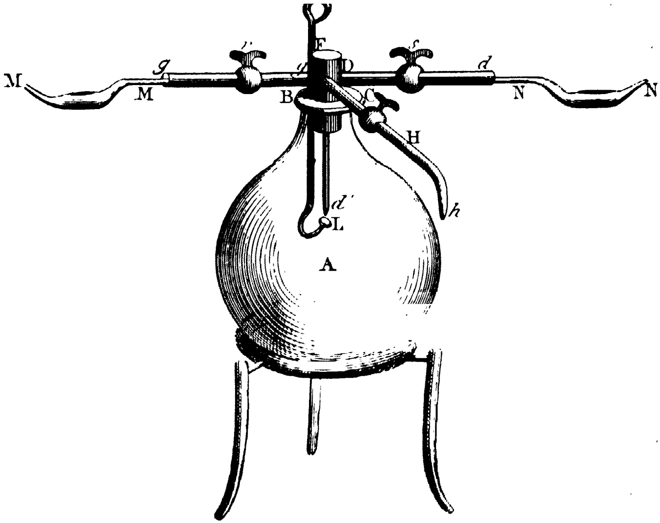
UP till about 1785 Lavoisier found among the chemists practically no support for his new theory of combustion. Some of his personal friends, mathematicians and physicists, among the members of the Academy, were early converted to the new doctrine, and while it must have been gratifying to him to know that his experiments and arguments appealed to men with logical minds, he would have liked to win over to his views such men as Cavendish, Priestley, Scheele, Fourcroy, and Berthollet, for whom and for whose work he had a great admiration. Nevertheless, he never showed any irritation at the conservatism of his fellow chemists; in fact, he stated explicitly in his paper on phlogiston that he did not expect his ideas to be adopted immediately; he was content to leave them to the test of time. At the same time he noted with satisfaction that many young men who were approaching the subject with unprejudiced minds were now embracing the new theory. As for the older chemists, he was content to wait, realising that in science new ideas must be received with reserve, and that scientists should not be blown about by every wind of doctrine. At the moment, Stahl's theory still held the field as far as the leading chemists were concerned. Lavoisier's experiments and arguments were specious enough, but they were received sceptically; everybody was waiting for somebody else to point out the fatal flaw.

Such was the state of affairs when the news reached Lavoisier in 1783 of certain new experiments that had recently been carried out in England by Cavendish. The latter had, in 1766, investigated in his usual thorough manner the properties of "inflammable air" (hydrogen), but since he had collected it over water he had not noticed the moisture formed when the gas burned. Priestley, in one of his "random experiments," exploded a mixture of "inflammable air" and common air in a glass globe which, although dry before the explosion, was covered with moisture inside after the explosion had taken place, a fact that was noticed by his friend Waltire. Priestley thought nothing of this, considering that the moisture had been present originally in the air and had simply been deposited by its phlogistication. In 1781 Cavendish, as a result of his passion for detail, followed up this apparently trifling observation, and during the next two or three years he was led to undertake a long series of experiments which was of the greatest importance to the progress of chemistry. After exploding mixtures of "inflammable air" and common air in various proportions, he concluded that when "inflammable air" was exploded with about two and a half times its volume of common air "almost all the inflammable air and about one-fifth of the common air lose their elasticity and are condensed into the dew which lines the glass." Although this statement contains implicitly the discovery of the composition of water, Cavendish did not interpret his experiments in what is to us the obvious way. After showing that the " dew " was really water he exploded mixtures of " inflammable air " and " dephlogisticated air " and found that water was again formed. Surely now he would make the obvious deduction, but no; he considered that " dephlogisticated air " was water deprived of its phlogiston and that " inflammable air " was either water combined with phlogiston or else phlogiston itself. In either case the explosion of the two gases resulted, as it were, in the cancelling out of the phlogiston leaving water.

The paper in which Cavendish's experiments were described was read to the Royal Society in 1784, but it was in May or June of the previous year that Lavoisier heard about them. Blagden, who had just been elected secretary of the Royal Society, visited Paris and gave Lavoisier and other members of the Academy an account of Cavendish's researches. Now Lavoisier had also been experimenting with " inflammable air," and in particular had been trying to find the acid which, according to his theory of acids, ought to result from the union of " inflammable air," a combustible body which was not a metal, with oxygen, the acidifying principle. In 1777, along with Bucquet, he had burned " inflammable air " in vessels containing lime-water and had shown that no " fixed air " was formed. In 1781, along with Gengembre, he had burned oxygen in " inflammable air," the containing vessel holding successively lime-water, distilled water and an alkali; the lime-water showed no turbidity, the distilled water remained pure, and there was no change in the alkali. It is rather surprising that in the course of these experiments he failed to notice the formation of water. Was it because he was so obsessed with his oxygen theory of acids? It looks like it; he did not approach the experiments with an open mind determined to learn what they had to teach him. He was trying to find an acid, and could not see anything else. Even great men have their lapses.

Macquer and Monge, both contemporaries of Lavoisier, had each obtained water by the burning of "inflammable air," but as their work was unknown to Lavoisier at the time of Blagden's visit, it was really Cavendish's work that set him on the right path and led ultimately to his announcement of the non-elementary nature of water. Lavoisier and his friends were very sceptical about Cavendish's experiments; they were inclined to think, as Priestley had done, that the water formed as a result of the combustion of "inflammable air" must have been pre-existent in the gas or in the atmosphere. To confirm or controvert this opinion Lavoisier was asked to repeat the experiment on a large scale. This he did as speedily as possible, and he considered the result important enough to justify his sending at once a short account of it to the Academy.

Here again Lavoisier showed that unfortunate moral twist in his character which he had exhibited in the matter of the discovery of oxygen, for when the



GLOBE USED FOR THE COMBUSTION OF HYDROGEN AND OXYGEN

full account of the experiment appeared in the Memoirs of the Academy, the part played by Blagden was dismissed as follows: "It was on the 24th of June that M. de Laplace and I made this experiment in the presence of MM. le Roi, Vandermonde, and several other Academicians, and of Mr. Blagden, the present Secretary of the Royal Society of London. The latter informed us that Mr. Cavendish had already tried in London to burn inflammable air in closed vessels and that he had obtained a very appreciable quantity of water." There is little doubt that Lavoisier wished it to appear that Blagden's presence was merely incidental, that he had happened to drop in at the demonstration of an experiment which had been planned quite independently of any information received from the visitor. The fact that others had been present when the information was given did not seem to deter Lavoisier from claiming to have been the originator of the experiment, and this renders his conduct almost deserving of the term unscrupulous. As in the previous case, he is entitled to, and has always received, all the credit for the correct interpretation of the experiment, but there is no doubt at all that it is to Cavendish that we must assign the priority of the experiment itself.

Cavendish, the shy, timid, retiring philosopher, would never have dreamt of disputing Lavoisier's implied claim, but Blagden, smarting under the injustice done to his friend, made a public protest in which, after relating the circumstances in which he came to acquaint Lavoisier of Cavendish's experiments, he proceeded to accuse him of suppressing the truth. "In general," he said, "Mr. Lavoisier cannot be convicted of having advanced anything contrary to the truth; but it can still less be denied that he concealed a part of the truth; for he should have acknowledged that I had, some days before, apprised him of Mr. Cavendish's experiments, instead of which the expression '*il nous apprit*' gives rise to the idea that I had not informed him earlier than that very day. In like manner, Mr. Lavoisier has passed over a very remarkable circumstance—namely, that the experiment was made in consequence of what I had informed him of. He should likewise have stated in his publication not only that Mr. Cavendish had obtained '*une quantité d'eau très sensible*,' but that the water was equal to the weight of the two airs added together. Moreover, he should have added that I had made him acquainted with Messrs. Cavendish and Watt's conclusions—namely, that water, and not an acid, or any other substance, arose from the combination of the inflammable and dephlogisticated airs. But *those* conclusions opened the way to Mr. Lavoisier's present theory, which perfectly agrees with that of Mr. Cavendish, only that Mr. Lavoisier accommodates it to his old theory, which banished phlogiston. . . . The course of all this history will clearly convince you that Mr. Lavoisier (instead of being led to the discovery by following up the experiments which he and Mr. Bucquet had commenced in 1777) was induced to institute again such experiments solely by the account he received from me of our English experiments; and that he really discovered nothing but what had before been pointed out to him to have been previously made out and demonstrated in England."

To this grave protest neither Lavoisier nor any of those present at the experimental demonstration replied. If the facts had not been as Blagden stated, would Lavoisier not have hastened to defend himself against these aspersions on his integrity?

This aspect of Lavoisier's character is very distressing. One can understand the motive of a man of mediocre ability and attainments trying for the sake of personal advancement to appropriate the discoveries of others, but Lavoisier was already in the forefront of scientists and his genius had already gained for him a world-wide repute. Possibly the fact that the discovery of oxygen and of the composition of water had just eluded him, when in each case he had been on their track, so tantalised him that he considered he was entitled to claim all the credit for the crucial experiments. No special pleading, however, can completely exonerate him from the charge of attempting to pick the brains of Priestley and Cavendish. Because of his eminent services to chemistry one would like to gloss over his faults, but in the cause of accuracy and in justice to the two English chemists the facts must be stated. If he had only known, his name was to live in history in virtue of his own achievements as that of the man who was entirely responsible for the overthrow of the phlogiston theory and who ushered in a new era in chemistry.

To return to June 24th, the experiment was a very crude repetition, hastily undertaken, of the one in which Cavendish had burned "inflammable air" in oxygen. The gases were contained in separate reservoirs, from which they were conducted in leather tubes to a bell-jar standing over mercury and there burned. Drops of moisture ran down the sides of the jar and about half an ounce of a liquid, which proved to be water, collected on the surface of the mercury. Those present expressed the opinion without giving any evidence to support it that the weight of water formed was equal to the sum of the weights of the two gases which had disappeared, and Lavoisier's general deduction from the experiment was that water was not an elementary substance, as had hitherto been supposed, but that it was a compound consisting of "inflammable air" and oxygen. Cavendish had foreseen this possible explanation, and it was expressly given in his paper, but he preferred the phlogistic explanation: "as the commonly received principle of phlogiston explains all phenomena, at least as well as Mr. Lavoisier's, I have adhered to that."

Lavoisier announced the conclusion he had come to in a paper read to the Academy in November, 1783—"Memoir whose object is to prove that water is not a simple substance, an element properly so-called, but that it is capable of decomposition and recomposition." The experiment above referred to was later repeated with a view to obtaining a quantitative result, and this work was embodied in the paper before it was printed. The ratio by volume was found to be 12 parts of "vital air" to 22,924345 parts of "inflammable air," which was a poor result compared with Cavendish's, in spite of the number of decimal places ! From the (inaccurate) densities of the gases the composition by weight was calculated to be 0,86866273 parts of " vital air " to 0,13133727 parts of " inflammable air." It is obvious that, in spite of his mathematical training, Lavoisier's ideas about significant figures were rather hazy.

As far back as 1773 or 1774 Lavoisier had planned to write a treatise on water. He intended to treat successively methods of finding the specific gravity of water, the use of this constant in determining the purity of water, methods of identifying the particular salts present in impure water, the thermal expansion of liquids in general and water in particular. That was to constitute Part I. The second part was to contain an account of his experiments on the alleged transmutation of water into earth and of " experiments which prove that water is not decomposed by any means known up to the present." He never completed the book, but he made out a scheme for it, and actually wrote several chapters. If he had published it it would have been out of date in ten years.

One would have thought that the discovery of the composition of water would have led Lavoisier to change his views on the constitution of acids. The test of a theory is the power it gives to predict as yet unascertained facts. His theory had broken down under this test. Here was a substance, water, which contained oxygen, the acidifying principle, and was not a calx ; yet it was not an acid. He had been looking for the acid corresponding to the acidifiable base, "inflammable air," and he had obtained water instead. But he did not abandon or even modify his theory because of this awkward fact, which indicates that even the great Lavoisier was not immune from the weakness which he attributed to the phlogistians of trying to maintain a theory which was contrary to the evidence.

After having synthesised water Lavoisier next attempted to analyse it. He argued that if water were really composed of "inflammable air" and oxygen, then it ought to be possible to decompose it by presenting to it a substance for which oxygen had a greater affinity than it had for "inflammable air," and he suggested the possibility of using iron, zinc, or charcoal for this purpose. He received a useful hint from the published work of Bergman, the Professor of Chemistry and Pharmacy at Upsala University, who had shown that if iron filings were immersed in distilled water for a considerable time they were changed into "martial ethiops" (magnetic oxide of iron), while "inflammable air" was liberated. This experiment Lavoisier repeated and with the same result.

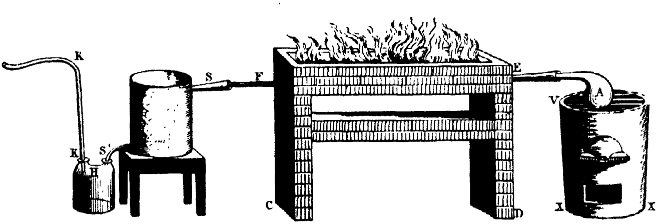
Meanwhile, Priestley had carried out some experiments "made with general and indeterminate views," in which he had shown that, in modern terms, metallic oxides were reduced by hydrogen. Since in the process all the "inflammable air" disappeared and no other gas was evolved, he had concluded that "inflammable air" was probably pure phlogiston, and that what we now call a reduction was really a combination. The small quantity of water produced he regarded as having been originally present, either in the calx or in the gas—he could not make up his mind which. Lavoisier, who had been informed by Blagden of these experiments, saw in them further proof of the soundness of his ideas. After repeating the experiments, he pointed out that the calx diminished in weight by the action of " inflammable air " on it and drew the, to him, obvious conclusion that the " inflammable air " had united with the oxygen in the calx forming water and leaving the metal.

At this time, however, he was more interested in the analysis than in the synthesis of water. When the experiment with iron filings and distilled water was far enough advanced to enable him to confirm Bergman's result, he began to consider how the process might be speeded up. In collaboration with Meusnier, he devised the well-known experiment with steam and iron. In the first form of the experiment they used an iron gun-barrel. They coated it on the outside with clay and placed it in a furnace in a slightly inclined position. Water was allowed to trickle slowly into the barrel from a funnel, and the lower end of the barrel was connected to a worm condenser to collect any water that might escape decomposition. A bottle was provided for this water and a bell-jar standing in a kind of pneumatic trough to collect the gas. Actually they found that if the gun-barrel was red hot before the water was slowly passed into it all the water was decomposed. At first, " inflammable air " collected very rapidly in the bell-jar, but the rate of the reaction soon slowed down considerably until, after eight to ten hours, it stopped altogether. An examination of the inside of the gun-barrel revealed the fact that it was now covered with, and partly closed by, a coating of " martial ethiops." Thus the water had been decomposed into " inflammable air " which was collected and oxygen which had united with the iron.

When the experiment was repeated quantitatively, the percentage of " inflammable air " in water came out to be 8.

Since the gun-barrel was completely destroyed by the experiment, and since they realised that it was not possible to obtain good quantitative results by this method, it occurred to them to try a tube made of some other material. They found that water passed through a red-hot copper tube without decomposition. They therefore, in another experiment, used a copper tube, or rather an iron tube lined with copper foil, and placed in it some iron shavings, the apparatus being otherwise the same as before. Water was passed through the tube till " inflammable air " no longer appeared in the bell-jar, then the water was turned off and the tube allowed to cool. It was found that the iron had been changed into the black, friable, magnetic substance as before.

As in the case of calcination so with water ; Lavoisier had attacked the problem both analytically and synthetically. To unbiassed minds his demonstrations and arguments were conclusive. His oxygen theory of acids may have somewhat confused the issue, but an open mind would surely concede the compound nature of water. Yet even five years later he mentioned in the course of a report on a new



THE DECOMPOSITION OF STEAM BY IRON.

experiment by Séguin on water that " water is considered to be an element by most scientists." We can hardly understand this stubbornness to face facts.

The experiments just described were carried out at different times in 1783 and 1784, and are said to have cost Lavoisier about 50,000 livres. The following year he reverted to the subject of respiration. He had not been satisfied with his previous work in this connection, for the amount of expired carbonic acid did not quite tally with the amount of heat produced, which was greater than was evolved by the burning of an equivalent amount of carbon. In 1785 he discovered the reason for the discrepancy in the fact that the expired breath contained water vapour besides carbonic acid and azote (nitrogen). If the heat produced by the burning of a sufficient quantity of " inflammable air " to produce this water vapour were added to the heat produced by the burning of the carbon to form the carbonic acid, the sum equalled the amount of heat produced by respiration. Respiration, therefore, was a process of slow combustion, in which carbon and hydrogen in the body united with oxygen from the air, and animal heat was the direct result of this chemical change.

It was only now, in 1785, about ten years after his first public announcement of his new theory of combustion that the stronghold of phlogiston began to feel the effect of the battering ram of his experiments and arguments which it had, up till now, more or less successfully withstood. Certainly one or two minor breeches had been made owing to the disaffection of some of the French mathematicians and physicists, but the chemists had stuck to their guns and had held the fort. In this year, however, the desertion of Berthollet was a serious blow to the phlogistians. Convinced at last that he was fighting a losing battle, he went over to the enemy and thereafter he was one of Lavoisier's staunchest supporters. The following year de Morveau and, in 1787, Fourcroy capitulated, and with them they took the majority of the smaller French fry. In foreign countries the fight was not so successful. Scheele and Bergman in Sweden stuck to their phlogistic guns, and Priestley and Cavendish in England were impervious to assault; all these defended their positions vigorously and died fighting. Priestley's last published work, which appeared in the year 1800, was entitled "The Doctrine of Phlogiston Established." Only Black of the eminent foreign chemists, after a little hesitation, associated himself with Lavoisier's oxygen theory.

There is a story to the effect that after the successful series of experiments on the composition of water, Lavoisier and his friends held a solemn meeting in Paris at which Madame Lavoisier, in the habit of a priestess, burned on an altar Stahl's *Chemicæ Dogmaticæ et Experimentalis Fundamenta* to the accompaniment of funereal music. This, if true, was probably intended more as a lark than as an insult to Germany, but German science was shocked and disgusted; in Berlin, Lavoisier was burned in effigy as "a heretic of science."

Lavoisier and his circle of newly converted friends sought next to consolidate their position. It was probably de Morveau who suggested that a reform of the nomenclature of the subject, then a haphazard jumble of names many of which had long lost any meaning they might have had, would serve to spread the new chemical ideas. In 1787, de Morveau, Berthollet, Fourcroy, and Lavoisier collaborated in inventing a new system of nomenclature which they hoped would bring order out of the chaos of chemical names. Powder of Algaroth, Salt Alembroth, Martial Ethiops, Calcothar, Butter of Antimony, Flowers of Zinc—such names conveyed nothing of the nature of the substances they represented, and it was the object of the four collaborators to alter all this and to make the names suggest ideas. Oxygen and hydrogen were cited as good examples of the new kind of name from which anyone with an elementary classical education would extract some information about the substances so named. Hassenfratz had suggested a complicated system of symbols designed to represent all substances and their properties, but the authors rejected this as being too artificial and rigid.

Coming now to their own suggestions, they proposed to leave the names of the elements as they were. In the names of the acids only slight changes would be necessary to differentiate between two acids containing the same element, for example, sulphuric and sulphurous acids, but since they were acids the presence of oxygen need not be specifically indicated. Compounds of oxygen with the metals they called oxides and other binary compounds were designated by the termination *-ure*; for example, sulphure of lead, phosphure of copper, carbure of iron. Salts, being compounds of oxides and acids, should indicate this fact in their names; for example, sulphate of copper, sulphite of copper, and similarly for others.

The action of the French chemists was greatly resented in some quarters; it was considered that they were trying to force the new ideas on the scientific world before they had been properly tested, and in so far as such criticism was not due to national jealousy and prejudice, there was something to be said for it. The French chemists have been universally praised by historians for their reform of the nomenclature which has stood to the present day very much as they left it, but it must be admitted that they were very fortunate in that later discoveries did not to any serious extent invalidate their work. They were just a little precipitate, and had they happened to proceed on wrong lines, wrong, that is, in the light of modern knowledge, they would have been severely criticised. There was really something in the contemporary criticism that although the new nomenclature was well adapted to the state of the science in 1787, new facts would probable be discovered from time to time which would make the nomenclature more and more imperfect. In other words, a period of transition was no time for making such a change, which depended on the theories of the moment.

On the other hand, a start had to be made some time and, if the basic principles were sound, modification would be an easy matter. Thomas Thomson, who made the criticism above outlined, not always in a very kindly manner, went on to say: "Indeed the establishment of a new nomenclature in any science ought to be considered as high treason against our ancestors, as it is nothing less than an attempt to render their writings unintelligible, to annihilate their discoveries, and to claim the whole as our own property." Here, of course, he overstepped the bounds of legitimate criticism.

Lavoisier, in his usual lucid manner, set out the position thus: "The impossibility of separating the nomenclature of a science from the science itself is due to the fact that every branch of physical science must consist of three things—the series of facts that are the subject-matter of the science, the ideas which represent these facts, and the words by which these ideas are expressed. Like three impressions of the same seal, the words ought to call up the ideas, and the ideas ought to be a picture of the facts, and as the ideas are preserved and communicated by means of words, it necessarily follows that we cannot improve the language of science without at the same time improving the science itself; and neither can we on the other hand improve the science without improving the language or nomenclature which belongs to it. However certain the facts of any science may be and however correct the ideas we have formed of these facts we can communicate only false or imperfect impressions of these ideas to others while we lack words by which they may be properly expressed."

The new nomenclature undoubtedly simplified the subject considerably (it was even said that chemistry would now be as easy to learn as algebra !), and if the French chemists did intend it to be a piece of propaganda in favour of the new chemical ideas, the move was an astute one and amply succeeded in its purpose.

What a blessing the new ideas turned out to be sound on the whole! Had they been seriously in error, progress might have been held up instead of receiving an impetus which has carried it continuously forward.

Much of the criticism of the new ideas, even when it was not personally abusive, was ill-informed and could well be ignored, but in 1788 there appeared a book by the English chemist Kirwan which, because of the author's integrity and standing, as well as because of the merits of the essay, called for some reply. Although it contained nothing new, it was an excellent *résumé* of the chief arguments of the phlogistians set forth clearly and logically. Madame Lavoisier translated it into French, and Lavoisier, with the assistance of his chief disciples, published this translation, each chapter being followed by a commentary in which Kirwan's arguments were rebutted one by one. Even after this detailed reply Kirwan held out for some time longer, but ultimately he announced his complete conversion to the new ideas. In 1792 he wrote to Berthollet: " At last I lay down my arms and abandon phlogiston." By this time the new system of nomenclature (1787) and the " Elementary Treatise on Chemistry " (1789) had been published, and they completed the downfall of phlogiston. In 1791, Lavoisier wrote in a letter to Chaptal: " To see the principles adopted which I was the first to announce is to me a great joy. The conversion of you, M. de Morveau, and a small number of chemists scattered throughout Europe was all that I aspired to and my success has surpassed my hopes, for I have received from all quarters letters which tell me of new proselytes, and it is only old men who have not the courage to begin their studies over again or who cannot bend their imagination to the new order of things who still cling to the doctrine of phlogiston. All the young people are adopting the new theory and from this I conclude that the chemical revolution is accomplished."

The year 1789, which marked the beginning of the political revolution, may be regarded as the virtual end of the chemical revolution. It had taken fifteen years to convert the scientific world from the theory that had outgrown its usefulness, but now Lavoisier's victory was all but complete. Curiously enough, two of his chief remaining opponents were Priestley and Cavendish, the two who, by their discoveries, had provided him with the most convincing proofs of the inadequacy of the existing views. After 1789 the British chemists practically abandoned the fight against Lavoisier's new doctrine, and chemistry in Britain suffered an eclipse, happily only a temporary one. The chemical text-books used in Britain were mainly translations of Continental books, those by Lagrange, Fourcroy and Jacquin being among the most popular. It was from these or similar books that Humphry Davy learned his chemistry.

Contrasted with the hostility exhibited by some foreign scientists, the appreciation of the representatives of science as a whole was very gratifying. Many of the French learned societies, including the Academy of Dijon, the Royal Society of Medicine, and the Agriculture Societies of Paris and Orleans, had honoured him by membership. The first foreign society to do him honour was the Helvetic Society of Basle, which admitted him to membership as far back as 1774. Between then and 1789 the Royal Society of London, the Society of Harlem, the Academy of Science of Padua, and the Philosophical Society of Philadelphia all made some official recognition of his eminent services to science. Had it been the custom then as now to award medals and honorary degrees, Lavoisier would undoubtedly have been the most be-medalled and the most be-hooded man in France, possibly even in the world.

CHAPTER IX

VARIOUS SCIENTIFIC ACTIVITIES

In the two preceding chapters we have dealt with only one of the various channels of Lavoisier's activities. For the sake of continuity his greatest contribution to science has been lifted out of its context and presented as a whole. It is now necessary to retrace our steps to 1775 and deal briefly with some of his other scientific work from that year to 1789, the year in which the French Revolution began. This narration may be rather in the nature of an anticlimax after the dramatic episodes in his war on phlogiston, but there are many points of interest which cannot be passed over without comment.

The year 1775 saw Lavoisier fully launched on his scientific and administrative career. On the scientific side, he was already beginning to feel his way out of the maze into which chemical theory had fallen, and he had been promoted from *adjoint* to associate of the Academy of Sciences in 1772 mainly on account of the thorough manner in which he had carried out the many investigations entrusted to him by his colleagues. On the administrative side, the work of the *Ferme Générale* absorbed a great deal of his time and thought, for, besides having his ordinary duties as a *fermier*, he was elected by his fellow *fermiers* to various committees appointed for the investigation of certain problems connected with the *Ferme.* The Gunpowder Committee also necessitated his attendance at meetings, and the carrying out of researches on the methods of obtaining nitre and of making gunpowder. In spite of, or possibly because of, the multitude of his activities he preserved excellent health. He was never, as far as we know, stricken by any serious illness, and if he suffered from slight indispositions from time to time they were considered too trifling to be put on record either by himself or by any of his friends.

One factor which contributed in no small measure to his success was the active assistance of his wife. When the disabilities under which she suffered owing to her tender years were overcome in natural course of time, she gradually blossomed forth as a cultured lady who could play the hostess with skill and grace, who could read English sufficiently well to be able to translate scientific works, who could assist her husband in the laboratory, and who could execute the drawings for her husband's books. The cynic may quote Madame Lavoisier as an example of what can be done with a wife by catching her young and training her properly, but it is more kindly and more in accordance with the facts to think that it was her profound respect and wifely affection for her distinguished husband that led her to cultivate her innate gifts so that she would be worthy of him.

Before she was nineteen years of age she was learning Latin and English, and had soon made sufficient progress in the latter language to be able to translate papers by Priestley, Cavendish, and other English scientists. Not long after her marriage she began to accompany her husband into his laboratory, particularly after their removal to the Arsenal where, indeed, she could hardly escape from it, for the laboratory was nearly co-extensive with the accommodation put at his disposal. She began to take notes, at Lavoisier's dictation, about the experiments in progress, and this constant contact with scientific work gave her an insight into the scientific problems of the day, so that she could take part in the technical discussions between Lavoisier and his friends. She made two sketches during the experiments on respiration.

It would be impossible, in the course of a short biography, even to mention all the diverse subjects which Lavoisier touched. His work has been collected by Dumas and Grimaux in six quarto volumes, running to about 4,500 pages. Much of it had no permanent value, but its nature and its scope testify to the width of his interests and the thoroughness of his work. His reports to the Academy will be dealt with in the next chapter; here an outline of some of his other original work will be given.

It has already been noticed that the year 1777 was a particularly busy and fruitful year. It was in this year that his new theory of combustion took definite shape and was given explicit utterance. In the same year, among several papers of minor importance read to the Academy, he gave two which are of special interest. In one, "On the Dissolution of Mercury in Vitriolic Acid," he gave for the first time the com·

position of this acid. He described how he had warmed gently a mixture of mercury and vitriolic acid which had effervesced briskly, evolving the gas we now call sulphur dioxide, but which he called "volatile sulphurous acid." Two years previously Priestley had obtained the gas by this method, but he had gone no farther than to note the obvious properties of the gas and this new method of preparing it. Lavoisier, on the other hand, continuing to heat till the solid product decomposed, discovered the presence of some "highly respirable air" as well, and concluded that "mercurial vitriol" was composed of mercury, "volatile sulphurous acid" and "highly respirable air," that is, mercury, sulphur dioxide and oxygen. Going a step farther, he drew the conclusion that vitriolic acid consisted of "volatile sulphurous acid" and "highly respirable air." Previously, sulphur, sulphurous acid, and sulphuric acid had been considered to differ merely in their degree of phlogistication.

The other interesting paper of this year was entitled "On the Vitriolisation of Martial Pyrites," and its object was to elucidate the reason for the fact that iron pyrites in certain circumstances was changed into "martial vitriol," that is, green vitriol or ferrous sulphate. His first experiment was to heat some iron pyrites in a closed vessel, the result of which was that sulphur sublimed on the colder parts of the vessel. Since at this time he was full of his new oxygen theory of combustion, he guessed that the vitriolisation was due to combination with oxygen. He therefore put some iron pyrites under a bell-jar over water and found that the water gradually rose in the jar till it finally occupied about one-fifth of the volume of the jar. Moreover, the remaining gas extinguished a lighted candle and gave no precipitate with lime-water; hence, it was " atmospheric mofette," that is, azote or nitrogen. Finally, the experiment was repeated, using oxygen instead of air in the jar, and this confirmed the fact that the vitriolisation was really the combination of oxygen with the pyrites.

Other chemical work carried out about the same period included the composition of " fixed air " or, as Lavoisier had called it, " chalky acid," which he now proposed to call " acid of carbon " ; an examination of Priestley's method of measuring the " goodness " or " salubrity " of the air by means of nitrous acid (nitric oxide) ; the quantitative replacement of one metal by another in which, while rejecting the phlogistic explanation of the phenomenon, he was rash enough to substitute oxygen for phlogiston, in this case pushing his theory too far ; a criticism of Bergman's tables of affinity in which he considered that such tables were premature because of the state of chemical knowledge.

Lavoisier was very interested in the compounds of iron, in particular the substance called " martial ethiops " (magnetic oxide of iron). We have seen that, in connection with his experiments on the composition of water, he obtained this substance by the action of iron on distilled water and on steam, but even before this he had made it by heating iron strongly in air and by burning it in oxygen. The latter experiment he performed in two ways. Some very thin iron shavings were put under a bell-jar full of oxygen and lit by touching a small piece of phosphorus with the curved iron rod he constantly used in such experiments. The other method, due to Ingenhouz, was to ignite a thin spiral of iron wire by means of an amadou in a manner similar to that now used in schools.

The study of the action of iron on acids led him to the opinion that when hydrogen was evolved it really came from the water and not from the acid. His argument ran somewhat as follows: no hydrogen is obtained by adding iron to pure sulphuric acid; this acid exposed to the air unites with water; if the acid is further diluted with water hydrogen can be obtained by adding iron; the hydrogen must therefore have come from this "free" water.

The successful collaboration of Lavoisier and Laplace, which resulted in the memoir on heat read to the Academy in 1780, was continued as time and opportunity permitted, and several papers embodying the results of their experiments and their theorising about the results were read to the Academy in the years 1781 to 1784. They tackled the problem of measuring the coefficient of expansion of glass and of metals. In order to be able to measure accurately the very small expansions, they arranged matters so that a telescope was tilted by the expanding rod and a scale placed at a considerable distance from the apparatus—sometimes as far as 1,200 feet—could be read through the telescope. They claimed that their error never exceeded $\frac{1}{600}$ inch. These experiments were carried out in the garden at the Arsenal.

This series was followed by some experiments on the determination of specific heats with fairly accurate results, on fusion, on " the passage of solid bodies to the liquid state by the action of caloric." The action of heat in causing expansion and liquefaction was thus explained: " If we gradually heat a solid body, if we continue to introduce into it and accumulate in it fresh quantities of caloric, its molecules separate more and more from one another, and at last a stage is reached when the molecules cease to be in the sphere of activity of their attraction; it is then that the body passes from the solid to the liquid state. Not only do the molecules not possess any cohesion among themselves, not only do they not exert any attraction on one another, but they tend to obey a repelling force which doubtless is impressed on them by caloric; they strive to separate from one another, and indeed they would scatter indefinitely in space if the weight of the atmosphere did not place an obstacle to this scattering." Here again we have the idea of a material but imponderable caloric. It is given even more explicitly in a later passage in the same paper. After showing that 1 lb. of water at 60° R. just sufficed to melt 1 lb. of ice at 0° R. (a fairly good result), the authors state: " The caloric introduced into the pound of water to raise it to 60° was employed to melt a pound of ice and combined with the ice to form water, so that water is really a compound of ice and caloric."

Lavoisier regarded all liquids as solutions of caloric in the corresponding solids, just as he considered gases to be solutions of caloric in the corresponding liquids. When a gas was liberated by the action of heat or of an acid on a solid, he considered that there had been a transference of caloric. That caloric was a real substance to Lavoisier is shown by the properties which he assigned to it; for example, he thought of it as having affinities just as any other element had. In order to explain the reversible reaction between mercury, oxygen, and mercuric oxide, he said that when mercury was heated almost to its boiling-point the oxygen in "vital air" had at this temperature a greater affinity for mercury than it had for caloric; hence the formation of the red solid, caloric being set free both from the "vital air" and from the mercury. When, however, the temperature was raised above the boiling-point of mercury, the reverse was true, caloric then having a greater affinity for mercury than it had for oxygen.

Of course, the doctrine was almost universally held at this time. In the earlier part of the century the Academy had offered a prize for the best essay on the nature of heat, and the winners, three in number, favoured the material theory as against the molecular motion theory. One would have thought, however, that Lavoisier, having demolished one figment of the imagination in phlogiston, would have at least suspected the existence of this other hypothetical substance, but if he did he gave no indication of it in any of his published work.

Lavoisier, essentially a chemist, by his study of heat reminds us that at this time heat was included in the subject-matter of chemistry (Black, a chemist, discovered latent and specific heat). Lavoisier studied heat phenomena because in so many chemical reactions heat was either required to initiate the change or evolved. He fully realised that temperature had a great influence on some chemical changes; in fact, one of his objections to Bergman's tables of affinity was that they did not hold good for all temperatures; he argued that a different set of tables would have to be constructed for each degree of temperature. He spent many many hours heating all sorts of substances, including precious stones—rubies, emeralds and amethysts—refractories, such as clay, lime and magnesia, and metals such as gold, silver and platinum, without, however, making any important discovery. In order to attain a higher temperature than was possible with the ordinary furnace or lens he devised a new furnace which was supplied with oxygen instead of air, and he also made use of the oxy-hydrogen flame, but this last was not his own invention.

Among other thermochemical investigations was the rough determination of the calorific values of different kinds of fuel. The transition from fuel to food was quite an easy one, and we find him giving a dissertation on beef-tea, the full title of his essay being "On the strength of beef-tea, on its specific gravity, and on the quantity of solid gelatinous matter it contains." He gave directions as to the best method of making this invalid food, and suggested that its strength could very conveniently be tested by means of a hydrometer, but his advice has not had any permanent result, for neither in the sick-room nor in the kitchen has the hydrometer become popular.

In 1786 Berthollet, who had been carrying out investigations with the recently discovered gas chlorine, made for the first time the substance we now call potassium chlorate. Immediately after its discovery and for some time afterwards it enjoyed the name superoxygenated muriate of potash, which, clumsy though it was, expressed quite well the composition of the substance as far as it was known. Since it was found to contain a very large proportion of oxygen, Berthollet suggested that it might well replace saltpetre in the making of gunpowder. Experiments on a small scale showed that a mixture of carbon, sulphur and the new substance did indeed explode better than the usual gunpowder mixture, and Berthollet and others whom he consulted saw that although France had already gained an advantage in having the best gunpowder in Europe, thanks to the efforts of Lavoisier and his colleagues on the Gunpowder Committee, she would gain even more by being first in the field with a new and still better explosive. One obvious disadvantage was that superoxygenated muriate of potash was very expensive to produce, but it was thought that that would probably be overcome as a result of further investigation.

It was decided to carry out some experiments under factory conditions, and in September, 1788, a start was made in making a quantity of the new substance at the Arsenal. In about a month a sufficient quantity had been prepared and the best proportions of the ingredients had been ascertained. The Essonnes factory had been chosen for the experiment, and at the end of October a party consisting of Berthollet, Lavoisier, Madame Lavoisier, Le Tort, the manager of the factory, Chevraud, a member of the Gunpowder Committee, and Madamoiselle Chevraud, his sister, made the journey to Essonnes.

On the morning after their arrival work began at six o'clock. Le Tort had made a special kind of mill for mixing the powder which, by an arrangement of levers, could be worked by a man protected behind a barricade of planks. The substances were carefully weighed, and as a further precaution against accident, a little moisture was added. The mixing began, but things did not go smoothly, for the moist substances stuck to the pestle and to the sides of the mill. Le Tort was foolhardy enough to stand close to the mill and, with a stick, try to prevent the powder from sticking. He made light of the danger to which he was exposing himself and merely smiled at the anxious warnings of the other members of the party.

About 8.15 a.m. they stopped the mixing to examine the powder, and found that as far as they could judge by a close inspection, it was now nearly homogeneous, and after leaving strict orders with the workmen as to the precautions to be taken, they adjourned for breakfast. Le Tort, although unconcerned about the risks he himself had run, bethought him that he might have left an unmarried man in charge of the mill instead of the foreman, who had a wife and family, but Lavoisier reassured him by reminding him of the protecting barrier which, even if an explosion did take place, would effectively protect the men.

After breakfast, all the party except Le Tort and

Madamoiselle Chevraud went to inspect a new kind of mill which had been installed in another part of the factory, and the other two went back to where the mixing was being carried on. In a few moments, the party having merely glanced at the new machine, proceeded to join the other two, but had taken only a few steps when there occurred a tremendous explosion. When they had recovered from the unexpected shock they rushed anxiously to where the shed had been, only to find that little of the shed or the mill remained and worst of all there was no trace of their companions who had preceded them. A short search, however, revealed that the two unfortunate people had been flung a distance of 30 feet by the force of the explosion. The girl had been killed instantaneously, while Le Tort died half an hour later. As showing the efficiency of the measures taken against this contingency, not one of the workmen was hurt, for they had obeyed orders by remaining behind the barricade which had stood the test.

Lavoisier, who at the request of the editor wrote an account of the accident for the *Journal de Paris*, seized the occasion to point out to the public the risks run by those who were engaged in the manufacture of gunpowder, but emphasised that accidents such as this did not intimidate them; they would carry on as usual in the full realisation of the dangers inseparable from this occupation.

Until near the end of the eighteenth century organic chemistry was mainly descriptive. The method of analysis of organic substances is due to Lavoisier, and it followed as a natural sequel to the discoveries of the composition of water and carbon dioxide. It had been noticed by several chemists that when substances like spirits of wine and wax burned water was produced, and Priestley had detected the production of carbon dioxide as well, but naturally no explanation of these facts could be forthcoming till the elements present in the products were known.

In 1784 Lavoisier had undertaken a series of experiments on the combustion of several solid and liquid fuels, including spirits of wine, olive oil and wax. He burned the substance in a known volume of air or oxygen over mercury, measured the amount of carbon dioxide produced by absorption in caustic alkali, and determined the weight of water by difference. Although his quantitative results were imperfect, due, partly at least, to the presence of impurities in the original substances (the spirits of wine he used, for example, must have contained a considerable proportion of water), and partly to his imperfect quantitative analyses of water and carbon dioxide, his method introduced a new analytical principle, that of converting a substance of unknown composition into compounds of known composition, a method which has been used ever since.[1] If a substance was not easily

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[1] Lavoisier suggested the use of this method in the analysis of inorganic substances. If given an unknown salt he would proceed as follows:

The salt = acid (non-metal and oxygen) + base (metal and oxygen).
Let x represent the acid and y the base.

Add vitriolic acid to the salt; then if the products are nitrous acid and vitriolated tartar (potassium sulphate)

$$\begin{aligned} x + y + \text{vitriolic acid} &= \text{nitrous acid} + \text{vitriolated tartar} \\ &= \text{nitrous acid} + \text{vitriolic acid} + \text{fixed alkali} \end{aligned}$$

$\therefore x =$ nitrous acid
and $y =$ fixed alkali.

combustible he heated it with mercuric oxide or red lead—a method which if it had been made known at the time would have assisted considerably the development of organic analysis. It was not generally known that he had used this method till the appearance of his complete works.

By such methods Lavoisier was led to make the observation that "in the vegetable kingdom—and, above all, in the animal kingdom, there are hardly any radicals which are composed of less than two substances, hydrogen and carbon; that often nitrogen and phosphorus are combined with them." This discovery may be regarded as constituting the origin of systematic organic chemistry. The substances which he found to contain only carbon and hydrogen he proposed to call hydrocarbonous or carbohydrous radicals. Such radicals on oxidation yielded acids, and he considered that they differed from one another only in the proportion of hydrogen and carbon they contained or in their degree of oxidation. The first degree of oxidation was tartaric acid, the second was oxalic acid, and third, acetic acid.

Even more striking was his work on fermentation. He made a mixture of weighed quantities of sugar, water, and yeast and found after several days that the vessel contained alcohol, a little acetic acid, besides water and some unused sugar and yeast, while a considerable amount of carbon dioxide had escaped. Before Lavoisier's time no explanation of fermentation had been arrived at because the composition of sugar was unknown. He himself had, much to his surprise, established that sugar was composed of carbon, hydrogen and oxygen, and he had called it "carbonised water." At first he thought that there might be some water of crystallisation in it, but he afterwards abandoned this idea in favour of the view that it was the oxide of a compound radical consisting of carbon and hydrogen. This being the case, fermentation was simply a splitting up of the sugar into alcohol and carbon dioxide so that it would be theoretically possible to make sugar from alcohol and carbon dioxide. Here again Lavoisier's quantitative results were very imperfect, but in spite of this he was able to give for the first time a reasonable explanation of a phenomenon which had been noticed by the ancients but had puzzled chemists for centuries.

This work on fermentation is further interesting because in the course of his description of it he mentioned incidentally two matters which show how he delighted to get down to bedrock and examine the chemical faith that was in him. Speaking of the composition of sugar, he said: "Although sugar is composed of hydrogen, oxygen and carbon, and contains, therefore, the principles of water, oil and carbonic acid, it really contains neither oil, water nor carbonic acid; it is a ternary compound which has properties very different from the various mixtures which can be formed with the constituent principles combined two at a time." We have here an explicit statement of the difference between a mixture and a compound.

It was here, also, that he made his famous enunciation of the Law of Conservation of Matter: "Nothing is created either in the operations of art or in those of nature, and it may be put forward as a principle that in every operation there is an equal quantity of matter before and after the operation, that the quality and quantity of the principles are the same, and that there are only changes or modifications. It is on this principle that the whole art of experimental chemistry is based. In all of this one must suppose a true equality or equation between the principles of the body under examination and those that are obtained from it by analysis. Thus, since grape-juice gives carbonic acid gas and alcohol, I can say that grape-juice = carbonic acid + alcohol."

CHAPTER X

REPORTS TO THE ACADEMY

During the twenty-five years of his connection with the Academy, Lavoisier had a hand in preparing about 200 reports. As a rule two or three members were appointed to report on a subject, which might be a book, a pamphlet, a patent medicine, an industrial product, or a scientific theory. Sometimes topics were raised by members themselves, sometimes the Government sent along problems about which it required advice and guidance. Many of the subjects considered by the Academy or its commissioners could be included in a scientific category only by stretching the meaning of the term to the uttermost, but none seemed to be too trifling to merit attention.

It is noticeable that after the year 1774 a large proportion of the reports which Lavoisier was commissioned to make were on chemical subjects. By that time his work on combustion and calcination had raised him to the highest rank among chemists, and the Academy recognised this by appointing him to serve on commissions which would afford him full scope for his special bent.

In 1775, in spite of the fact that this was a busy year in other respects, no fewer than thirteen reports for which Lavoisier was partly responsible were read to the Academy. One of these was on "Vegetable Rouge," of which a sample had been sent for testing. The commission made some historical allusions to the use of cosmetics in general, and decided that this particular brand of rouge was harmless and seemed to fulfil the purpose for which it was intended. One is inclined to suspect that in this and other instances the manufacturer had an eye to the advertising value of a favourable Academy report on his product, and the commission evidently had some such suspicion, for, visualising the austere precincts of the Academy being inundated with samples of all sorts of goods, they advised that in future such samples should not be accepted.

Reports on steel, thermal waters, tartaric acid, and the purification of oils followed in the same year, and in the year after there were one or two of more than usual interest. The Duc de Chaulnes had written a memoir on the fixed air liberated in the making of beer. The commission appointed to examine this memoir gave voice to the doubt then existing as to the nature of this gas. "It is a great question among chemists to know what is fixed air. . . . Is it an acid? Does it contain an acid in some way in a state of solution?" The Duc favoured the former alternative, and Lavoisier and his colleagues expressed the opinion that "fixed air is nothing else than an acid in the form of vapour." A similar problem presented itself when a memoir by Sage appeared in which he gave it as his opinion that volatile marine acid (hydrogen chloride) was really a compound of fixed air with something else whose nature had not been determined. The report was rather severe on this opinion, stating that fixed air and volatile marine acid had nothing in common except their acidity. This, on the other hand, was rather a rash statement to make considering the meagre knowledge chemists had about both gases and the many different views held.

Two years later the subject of fixed air cropped up again as a result of a memoir by Bucquet, and Lavoisier was again appointed to report on it. The work described by Bucquet was to a large extent a repetition of Black's on the decomposition of chalk and added nothing new. One of the suggestions made, that part at least of the fixed air which resulted from the action of marine acid on chalk might come from the acid, seems to indicate that Sage's view was not peculiar to himself. The report on this memoir contained one passage which was obviously directed, not at Bucquet alone, but at scientists in general. It read: " One fact solidly established is more precious in chemistry than a multitude of conjectures offered with assurance which, being later contradicted by experiment, serve only to delay the progress of science and to lead those who study it into wrong paths." In other words, the Academy asked scientists to give it well-authenticated facts and not baseless speculations.

Other subjects dealt with in the reports of this year (1778) included the nature of glass, the decomposition of sal ammoniac, the decomposition of nitrous (nitric) acid, metallic soaps (probably metallic stearates), and the geology of the Pyrenees. In this year Lavoisier, owing to the death of one of the pensionaries, was promoted to fill the vacancy.

In 1779 the Academicians and the general public were startled by an announcement by Sage that he had succeeded in extracting gold from the ashes of vines ! Certainly only a fraction of a grain had been obtained from a considerable amount of ash, but the fact, if it really was a fact, would probably have had disastrous results on the French vineyards. It turned out on investigation that gold was really obtainable by the method used by Sage, but that it did not come from the ashes. Sage had used minium in his experiments, and the whole chemical section of the Academy who reported on the matter was able to prove that the gold came from this. So the vineyards were safe.

The following year Lavoisier was engaged for the most part on reports of minor importance. The subjects included the causticity of metallic salts, arsenical acid, the nature of the earth which is the base of Epsom salts, and the winding of silk. But another matter, this time one of national importance, engaged the attention of the Academy. For some time there had been an uneasy feeling among the public that the State prisons were not maintained in a manner worthy of the prestige of the nation, and Necker, one of the most level-headed of French finance ministers, undertook to make an inquiry into the matter. He produced a scheme for the establishment of new prisons and submitted it to the Academy for its opinion. A commission of five, of whom Lavoisier was one, was appointed, and in the course of their inquiries they seem to have encountered a good deal of passive opposition from officials who evidently considered that their efficiency was being called in question. Indeed, it was they who were largely responsible for the state of affairs which the commission revealed. The Academicians were horrified to find that the prisons were incredibly filthy and verminous, and in their report they emphasised the necessity of introducing strict rules which would make for cleanliness and health ; an abundant supply of water and a good system of ventilation were recommended as the first and essential steps to this end. Unfortunately for the prisoners, who, in being deprived of their freedom, were liable to lose their lives as well in such unhygienic surroundings, the Necker administration came to an end in the year following the Academy report, so that this urgent reform was postponed indefinitely, and the prison officials, who had become apprehensive, soon relapsed into their easy-going ways.

The next three years saw reports on the separation of gold and silver by means of nitric acid, on Scheele's book " Air and Fire," of which the experimental part was highly praised but the theoretical views contested, and on the mephitism of wells, in which methods of clearing fixed air out of wells were considered.

In November, 1782, France was greatly excited by the news that two brothers called Montgolfier had ascended in a balloon to a height of about 70 feet. The balloon, made of paper and cloth, was open at the bottom, where a fire was lit which, by causing expansion of the air, rendered the balloon less dense than the atmosphere, so that it rose. As soon as the fire went out the air began to cool and contract, and the balloon fell gently to earth again. This explanation, however, was by no means generally accepted at the time of the first ascent. Smoke from the fire, since it rose into the air, must be light, some said, and it was this that caused the balloon to rise. Fire itself in some quarters was vaguely deemed to be the lifting material.

The invention of the aerostatic machine, as it was then called, was soon brought officially to the notice of the Academy, and the importance they attached to it is shown by the fact that they appointed no fewer than eight of their members to draw up a report on it. Lavoisier was one of those selected, and he soon showed that, not only did he understand thoroughly the scientific principles involved, but he also had a clear conception of the direction in which improvements would come. The first step the commission took was to invite the brothers to come to Paris and make a balloon there so that they could study it at first hand. They offered to defray all expenses, but the Government, with unwonted eagerness and generosity, insisted on bearing all the cost of the trial experiments. In September, in presence of the King and a large crowd of curious spectators, a successful ascent was made at Versailles. To the intense delight and astonishment of the onlookers the balloon rose to a height estimated at 1,500 feet, remained in the air for ten minutes, and finally came to earth about two miles away.

About a month later the first aerial flight in a balloon was made by Pilatre. He carried with him a supply of fuel so that he was able to remain in the air for a considerable time; whenever the balloon showed signs of dropping he replenished the fire, and the length of the flight was determined simply by the amount of fuel carried. Ten days later, two men ascended to a height of about half a mile.

The Academy commission, having examined the balloon and having all the data of the flights at their disposal, came to the conclusion that it was the rarefaction of the air, and not the gases formed by the combustion of the fuel, that caused the balloon to ascend, their reasons being that it must be open at the bottom and that it began to descend whenever cooling began to take place. On one occasion they noticed that the balloon was stationary in the air for a few moments, and this gave them the idea that they might be able to calculate the temperature of the air in the interior of the balloon, because if it was stationary its specific gravity must be the same as that of the atmosphere. The total weight of the fabric was 1,700 livres, and its capacity was 60,000 cubic feet; hence, knowing the weight of a cubic foot of air, the weight of air it displaced was 5,280 livres, from which, by the application of Archimedes' Principle, the weight of air actually present in the balloon under those conditions was 3,580 livres. This gave the specific gravity of the enclosed air as about two-thirds of that of air at ordinary temperature, and therefore the temperature of the air in the balloon must have been somewhere about that of boiling water.

In the meantime, the physicist Charles had in August shown that a balloon filled with hydrogen could be used very conveniently, and had suggested that many atmospheric observations could be made by the use of such machines. As a matter of fact, the Montgolfier brothers had thought of using hydrogen, but had rejected it on the score of expense. The commission could not decide whether hot air or hydrogen was the better; one was inconvenient but cheap, while the other was convenient but expensive. They already realised that this new invention was going to be an important one, and they hoped for the discovery of a new light gas which could be produced cheaply. Given this, balloons might then be used for getting to otherwise unapproachable places, for obtaining data in the study of meteorology, and for beacons. They concluded by advising the award of a prize of 600 livres to the brothers.

Lavoisier, who had taken an active part in the drawing up of this report and in the deliberations of the commission, had early realised the points on which it was necessary to concentrate if the new machine was to be more than a mere curiosity. He laid it down that the chief problems in connection with aerostatics were (1) the material used for the envelope must be light but strong; (2) the gas must be light and fairly easily produced; (3) a method must be discovered of ascending and descending at will without losing gas; and (4) a means of steering must be found. These are, of course, exactly the problems which modern designers of airships have had to face, and it is only within recent years that they have been solved in a satisfactory manner.

Hardly had he completed this work, and while he was conducting some of his experiments on the composition of water, than he was appointed to investigate another subject which was very much in the public eye. Mesmer, a Viennese doctor, claimed to have discovered a new fluid which could be transmitted from one person to another and which, he asserted, had marvellous curative powers; he called it animal magnetism. In 1778 Mesmer arrived in Paris, and patients simply flocked to him. The procedure was that the patients sat round a mysterious tub in which were several bottles supposed to be full of animal magnetism, and they were roped together, iron rods connecting the bottles to the diseased parts. Subdued light and soft music added to the mystery of the séance. Many marvellous cures were reported, and all Paris was agog with enthusiasm and excitement. After six years the Government began to consider that it was time that the phenomenon was investigated by men who were competent to form a calm and considered judgment on the claims put forward by or on behalf of Mesmer. A commission was appointed consisting of doctors and members of the Academy, and Lavoisier was one of those chosen.

Mesmer himself was not in Paris at the time the commission set to work, but a doctor called Deslon, who was one of Mesmer's ardent disciples, willingly agreed to afford them every facility for examining the subject. Lavoisier began on his own account to study the literature of the subject, and without further investigation came to the conclusion that it was nothing else than charlatanism. Here again Lavoisier fell below his own high interpretation of scientific method; he came to a conclusion on hearsay evidence alone. He argued, quite rightly, that it was extremely difficult to decide as to how much a cure might be due to the medicine prescribed by a doctor and how much to nature's own recuperative powers, and, we should add nowadays, how much to suggestion and auto-suggestion. While the cure of a disease was generally regarded as a proof of the efficacy of the remedy applied, the scientist would regard it merely as a greater or less probability which, however, might be changed to certainty by the accumulation of a large number of facts of the same kind. He dismissed the alleged cures, however, and stated that what the commission must decide was not the reality of the cures, but the existence of animal magnetism. He himself considered that it did not exist, and that the cures, if they were indeed cures, must be due to other causes. The commission, themselves prejudiced and no doubt influenced by Lavoisier's exposition, reported on the lines of his argument. The report was not worthy of a body of scientists. Lord Dewar said recently: "Minds are like parachutes; they function only when they are open." Whatever were the merits or demerits of Mesmer's work, whatever the theory by which he explained it, it deserved at least unbiassed consideration, and if he did effect cures the fact should have been recorded in the report. If his theory was wrong it ought to have been put right, or at least an attempt made to do so. But after all, as has been remarked before, scientists are human; they are heirs to the failings and shortcomings of the human race, and although by their training they are able to throw off many of them, there is often a residue which makes itself felt. Possibly the unfortunate term "animal magnetism" was the real cause of the hostility of the commission, for it implied a theory and was not merely descriptive.

In 1785 Lavoisier's energies were diverted into a different channel. He was appointed Director of the Academy for that year, and hence had little time to devote to the making of reports, for the duties of Director were many and varied; they were similar to those of a manager of a large business concern. In general, he had to see that everything went smoothly, which, in particular, meant drawing up the programmes for the meetings of the Academy, seeing to the publication of the memoirs, jogging the memory of the secretary and outsiders who did business with the Academy, presenting newly elected members to the King and his ministers. He took his duties very seriously, and the amount of correspondence he had and the number of personal visits he paid in the execution of the duties of his office were extraordinary, especially when it is remembered that for him it was not a full-time job.

During the year after Lavoisier's appointment to this post some modifications were made in the constitution of the Academy. Twenty years previously Lavoisier, then on the very threshold of his career, had written to the secretary of the Academy deploring the lack of recognition of the science of experimental physics, and attributed to this the arrest of the progress in this department of science in France. Nobody had followed up the work of Huyghens and Mariotte, and he might have added, Pascal, and he had blamed the Academy for its lack of encouragement. Whether his contention was right or not, the fact that the study of the subject had been neglected remained, and now that he had some influence and prestige in the body which he had before criticised, he could carry into effect the reform he had advocated. He therefore put forward his proposals, and after discussion and amendment the necessary changes in the constitution were made.

Two new classes were created in the Academy—one for general physics and the other for natural history and geology. Metallurgy and agriculture also received recognition, and were merged with chemistry and botany respectively. This, however, would have had the effect of making the numbers unwieldily large, or tending in that direction, besides diminishing the exclusiveness of the Academy. To prevent this, and also to reduce the somewhat humiliating distinctions of rank, the class of *adjoint* was abolished and the number of associates in each class increased from two to three.

This reform was not accomplished without a good deal of trouble. Lavoisier was accused of intrigue—of, in modern slang, " wangling." The members had to be arranged in order of seniority in the different classes, and, in spite of the fact that nearly every member gained by the reorganisation, there were protests on all sides. Lavoisier, as the moving spirit in the change, had to bear the brunt of the attack and had to use all his tact in pacifying indignant members who had been, or considered they had been, offended.

At last general satisfaction was attained and the scheme was passed.

His year of office completed, Lavoisier was again appointed to numerous committees for the preparation of reports. During the next three years he assisted in the examination of, among other matters, coal measures, iron works, salt works, argentiferous lead mines, the making of glass, peat, the making of sugar, and lightning.

CHAPTER XI

DOMESTIC AFFAIRS AND SCIENTIFIC FARMING

LAVOISIER's early successes made his father a very proud man, and, although he did not live to see his son in the forefront of science, he saw enough to realise that there was a bright future before him. As early as 1772, almost as soon as the marriage celebrations were over, Lavoisier the elder sought to establish his son securely in a good social position. He probably considered that Antoine, already associating with the leading scientists in the Academy and with some of the leading business men in the *Ferme Générale*, would feel more comfortable in such intercourse if he could meet them on equal terms. At any rate, he conceived the idea of obtaining for himself some official post which would confer on him and his heirs noble rank. At that time there existed in France about 4,000 such posts, many of them sinecures which could be obtained—at a price. If the holder of one of them found himself in straitened circumstances, he looked around for a purchaser and sold to the highest bidder. M. Lavoisier succeeded in obtaining a post which was one of the most sought after; it enjoyed the grandiloquent title, *Conseiller-sécrétaire du roi, maison, finances, et couronne de France.*

The elder Lavoisier was by no means a robust man, and during the winter of 1767–1768 he had a very serious illness which seems to have left him physically much weaker. In 1771 he decided to retire from his post of *procureur au parlement* on account of his continued ill-health, which with advancing years he felt he could hardly expect to improve sufficiently to enable him to carry out his duties satisfactorily. Then came Antoine's marriage, his first assault on the problem of combustion, the publication of " Physical and Chemical Tracts," and his appointment to the Gunpowder Committee. Thus the early promise of his youth was being fulfilled, and his father and all who knew him intimately rejoiced in the young man's success. This was an earnest of what was still to come, but the father did not live to see the son reach the pinnacle of fame. Suddenly, in September, 1775, at the age of sixty, he was stricken with a fit of apoplexy and died.

This was a great blow to Lavoisier, between whom and his father there existed a strong bond of affection. Although they had not lived in the same house for nearly four years, there was constant coming and going, and Lavoisier's feelings for his father were those not only of filial respect, but also of devotion and complete confidence; his best friend was his father. A few days after his bereavement Lavoisier, in the course of a letter to an aunt, wrote: " You know and have often been a witness of the tender affection which always united us and of the confidence he had in me since my childhood. You can therefore judge how cruel this separation is. He did nothing but good and never did a bad turn to anyone, so he no doubt enjoyed the reward of the righteous, and I hope that his spirit of uprightness, of equity, and of integrity will serve as a guide to me after his death as it has served me as an example and a model during his life."

When Lavoisier removed his household to the Arsenal his aunt—that tender soul who sheltered his childhood from the blasts of a motherless world and who now basked in the sunshine of his youthful success—accompanied him; indeed, it was almost a foregone conclusion that she should. In ordinary circumstances, this arrangement would probably have had dire results in the shape of domestic infelicity arising from the mere presence, however self-effacing, of a third person in the home of the newly-weds; but in this case the extreme youth of the bride was no doubt sufficient reason for the fear that Antoine still required the care of his aunt. No doubt, too, young Marie, intelligent girl as she was, would learn much of household management at the hands of Aunt Constance, and she would be glad of her company during her husband's frequent absences from home.

Mademoiselle Punctis lived long enough to see her nephew a scientist with a European reputation, but she died in 1781 before his success was complete. Thus Lavoisier lost another guide, counsellor and friend, one who perhaps more than any other, not excepting his father, had helped to shape his character, one who, by example and precept, had set before him high ideals, one who assisted and encouraged him to his success.

At this time Lavoisier's home and laboratory at the

Arsenal was the centre of scientific activity in Paris. Here everybody who was a scientific anybody found himself before long. There was always something new to see and discuss: a new and exact barometer, some specially constructed thermometer, a very sensitive balance, or perhaps a new experiment or an old experiment with a new turn given to it. And Madame Lavoisier, having now attained the years of discretion, dispensed hospitality and scientific gossip with equal facility. Hardly a day passed but some visitor found his way to the Arsenal, and often several assembled to witness a new experiment or discuss a new theoretical point.

Arthur Young, in his "Travels in France"—that sometimes dull, often witty, but usually illuminating, diary of his journeyings in France—tells of a visit he paid to Lavoisier with a letter of introduction from Priestley. "To Mons. Lavoisier by appointment. Madame Lavoisier, a lively, sensible, scientific lady, had prepared a *déjeuné Anglois* of tea and coffee, but her conversation on Mr. Kirwan's Essay on Phlogiston which she is translating from the English, and on other subjects, which a woman of understanding that works with her husband in his laboratory knows how to adorn, was the best repast. That apartment, the operations of which have been rendered so interesting to the philosophical world, I had pleasure in viewing. In the apparatus for aerial experiments, nothing makes so great a figure as the machine for burning inflammable air and vital air, to make, or deposit, water; it is a splendid machine. . . . Mon. Lavoisier, when the structure of it was commended, said, *Mais oui monsieur et même par un artiste Francois!* with an accent of voice that admitted their general inferiority to ours. . . . His pond of mercury is considerable, containing 250 lb., and his water apparatus very great, but his furnaces did not seem so well calculated for the higher degrees of heat as some others I have seen. I was glad to find this gentleman splendidly lodged, and with every appearance of a man of considerable fortune."

Lavoisier's wealth enabled him to entertain on a lavish scale, and the dinners he gave amply fulfilled the prophecy jokingly made by one of his friends when he decided to enter the *Ferme Générale.* His wealth also left him free from the struggle against poverty so common among scientists, and with his noble rank allowed him to meet all on a footing of equality. He was visited, not only by those with scientific interests, but also by statesmen and successful men in other walks of life, and his house was the centre of social and intellectual activity, a centre, too, from which not a breath emerged of scandal or vice which polluted the aristocracy at this time.

Besides all his original work, his reports to the Academy and its weekly meetings, his tours of inspection for the *Ferme Générale*, the meetings of the Gunpowder Committee, and research work and organisation of the national factories under the control of the committee, he was often consulted by the Government on various matters on which they required expert advice, and he maintained a huge correspondence to which he gave the closest care and attention. Grimaux, who examined all his correspondence, tells us that he was in the habit of making a draft of a letter first, then writing it out in full, sometimes rewriting it, having it copied by a secretary, and even amending the fair copy before sending it off. For a busy man this constant striving after verbal perfection is truly remarkable; the ordinary friendly greeting received as much care as the important business letter or chemical memoir.

In the course of his journeyings in his capacity of *fermier générale* and as geologist, Lavoisier came in personal contact with farmers and peasants, and the deplorable condition of agriculture distressed him. He listened with a sympathetic ear to the tales of woe which the agricultural labourers had to tell and to the hardly less hopeless stories of the farmers. Farmers are proverbial grumblers, but it must be admitted that in the eighteenth century the French farmers had really substantial cause for complaint. The crushing burden of taxation, insecurity of tenure, and lack of credit facilities strangled all initiative and induced an attitude of miserable despair. Lavoisier saw all this, understood their plight, but did not pass by on the other side. His fellow-creatures, less fortunate than he, were not simply objects for his pity; they and their condition constituted for him a problem. He did not admit that the position was without hope; he did not admit that the farmers' conditions were entirely outwith their control. The demands of taxation were certainly onerous, the customs which had survived from feudal times were iniquitous, but, on the other hand, farming practice was crude and almost primitive.

Lavoisier's views on economics inclined to those of the physiocrats, who had adopted the doctrines of Quesnay as expounded in his book "La Physiocratie," published in 1767. Their main thesis was that the land was the sole source of wealth, and that all other occupations, while they might be necessary or desirable, did not add to the sum total of national wealth. Lavoisier put it thus in 1787: "Commerce and industry can use only the material which it (agriculture) has provided; so that it is the original source, the almost unique source, of all national wealth." If this was the case, then it was obvious that the only method of getting the nation out of the financial slough into which it had fallen was by stimulating agriculture. Some of the physiocrats agitated for the amelioration of the conditions in which the farmer had to labour, but Lavoisier attacked the problem from the other end; could the productivity of the land be increased under existing conditions? Lavoisier did not know, but he determined to try to find out.

With this aim in view he bought for 229,000 livres an estate called Fréchines in 1778, where he ultimately established an experimental farm. When he had made his plans he found that he had not sufficient space for his experiments, so he purchased some of the surrounding land. He contrived to spend two or three weeks twice a year at Fréchines, and a local friend who was interested in the experiments exercised general supervision in his absence.

For the short time each year that he sojourned at Fréchines he was a veritable lord of the manor of the

English country squire type. He got to know all his tenants, and was frequently called in to compose a quarrel between neighbours or to correct a wayward son, and generally to act as a father to the peasants. He visited the sick and gave them moral and financial assistance, and he established a free school in order that the rising generation would have a better chance in life than their parents had had. In those days of oppression Lavoisier's advent, with his humane and even kindly treatment of those in his service, must have meant much to the simple country folks, accustomed as they were to being treated as of less account than the animals they drove. The great scientist is often pictured as one who is not only dry as dust, but hard as iron; he is thought of as being somewhat aloof from his fellow-men, out of contact with everyday affairs, and, in fact, rather disdainful of matters not directly connected with his own interests. Such opinions feed on the tales about absent-minded professors and eccentric recluses, but as a matter of fact the proportion of such exceptional characters must be at least not greater among scientists than among, say, literary men. Lavoisier, at any rate, did not belong to the small minority. To a calm and judicial scientific mind he added an emotional and sympathetic temperament and a generous disposition. He was affable and sociable, a loyal friend, and a considerate master, one who befriended and actively defended the underdog.

His estate at Fréchines extended to about 1,200 acres. He divided it into four approximately equal portions and set on foot a series of experiments in cultivation which, if they did not lead to results which were of very great permanent importance, at least attained a large measure of local success. In fifteen years the amount of grain harvested on his estate was doubled for the same acreage, and he had five times as many cattle and sheep as he started with. He introduced to this particular part of the country potatoes and turnips, and demonstrated that the yield of land could be increased by allowing it to lie fallow periodically. This fallow land could be used for grazing, and by penning sheep and cattle systematically, fencing off first one portion then another, the land would be thoroughly manured and would yield a greatly increased crop in succeeding years.

All this, of course, took time. One of the disabilities under which agriculturists worked was that the results obtained were not immediate, and besides, when obtained, they could not, under the existing system, be applied. The changes that Lavoisier advocated in agricultural practice needed first and foremost money. It is said that he himself spent about 120,000 livres on his experiments. It was the financial aspect of his suggestions that proved the stumbling-block, for leases were short; and what farmer would spend a large sum of money in improving his farm when his lease might not be renewed? Besides, were not the farmers liable for *corvée*, *taille*, and a dozen other impositions which swallowed up any profit there might be on the working of the farm? Lavoisier therefore appealed to capitalists, and even to the Government itself, to invest money in agriculture, which, he assured them, would be doubly productive—it would earn interest, and it would give new life to an industry which would, in turn, stimulate national prosperity.

These experiments at Fréchines attracted the attention of agriculturists, and in 1783 Lavoisier was elected a member of the Paris Agricultural Society, which had been founded in 1761 to promote the interests of agriculture in France. In 1785 he was appointed a member of the Agricultural Committee, a consultative body set up by the Government to give advice on the various suggestions which were addressed to the Government from time to time. Lavoisier was made secretary of the Committee, which entailed writing the minutes of each meeting, and he soon became the moving spirit of the Committee, as an enthusiastic secretary often is. He drew up the plan of procedure, and on his suggestion it was decided to refer all questions with which the Committee did not feel competent to deal either to the Academy of Sciences or to the Agricultural Society. He suggested acquiring a piece of land for the purpose of carrying out experiments, and offered to place his own estate at the disposal of the committee.

There were no half-measures with Lavoisier: when he took a thing up he did it thoroughly. He soon became recognised as an expert on agriculture. As the experiments at Fréchines showed definite results, he prepared long papers which he read to the Paris Agricultural Society, and at the request of the Agricultural Committee he drew up a series of instructions which were published under Government auspices and sent to the Provincial Assemblies.

He kept pointing out that agriculture in England was in a much healthier condition than it was in France. Why was this? Why did an acre in England produce two-fifths more than a similar area did in France? It was not that the French were less industrious than the English; it was not that the English land was better: no, it was because the French farmers were weighed down under an almost unbearable burden of taxation, because the subject had not been scientifically investigated, and because capitalists had invested their money in concerns which gave a better prospect of immediate gain. He pointed out that money was necessary to purchase new seed and to obtain from abroad new breeds of cattle and sheep. He emphasised, too, that it was not sufficient for the Provincial Assemblies simply to pass on the instructions of the Agricultural Committee to the farmers in their districts, but also to "join example and encouragement to precept." Money spent on the establishment of experimental farms would be money well spent. As always, his appeal was to experiment. To the Government he pointed out the obstacles to progress in the shape of the survival of oppressive customs. To the landowners he showed the way to a greater productivity by following up and expanding the experiments he himself had initiated. His advice was unheeded; his reports were allowed to "lie on the table." The ruling classes would not forego their privileges; the lot of the peasant was no concern of theirs. The time was not far distant when the peasant was to rise and turn the tables on the tyrants.

CHAPTER XII

POLITICS

IT is a debatable point as to whether scientists as such should be invited to take an active part in the Government of a country. It is averred that a man eminent in scientific research may be a fool in other respects, that although one faculty of his mind may be in excellent working order, others needed for the consideration of problems in a different field are atrophied. On the other hand, it is maintained that a nation would lose rather than gain by the transference of some of its best scientific brains to the political sphere, because thereby scientific progress would be held up. One thing is certain, that few scientists would willingly become members of parliament, where the party machine is greater than conscience and where the number of superfluous words is so large and of beneficent deeds so small.

Lavoisier, although he took no active part in political affairs until towards the close of his life, held strong views on some of the burning questions of the day. His tours in the provinces had, as we have seen, brought him into personal contact with the peasants, and he fully realised and deeply deplored their miserable conditions of life. He was fully aware, too, that the agricultural reforms which he advocated would to a large extent be of no avail as long as the anachronistic system of taxation obtained. He saw with a sympathetic eye that the peasants had gradually lost during the preceding two or three centuries the rights to which they had formerly been entitled, while at the same time they continued to pay for them; and he saw that the privileged classes, indifferent and even callous, held and would stoutly defend the ruling position. He took in the whole situation in a manner which reminds us of his work on combustion. He read up the political history of the country, made use of his personal observations, and came to certain conclusions as to measures that might be taken for the amelioration of the lot of the peasant and the general good of the country.

It was not till 1787 that he got a suitable opportunity of making his views public. In that year a scheme instituted by Necker was carried through by Calonne for the setting up of a number of what were called Provincial Assemblies, which were really local parliaments, whose members, however, were chosen by the King. Lavoisier was chosen to sit in the Orleans Assembly, which consisted of twenty-five members—six representing the nobles, six the clergy, twelve the Third Estate, or Commoners, and a president, who was the Duke of Luxemburg. Lavoisier, in spite of the fact that he held noble rank, was one of the Third Estate representatives, a fact that indicates that his democratic views were well known.

The first session of the new Assembly was fixed for September 6th, and two days previously Lavoisier, accompanied by his wife, set out for Orleans, a journey which occupied the best part of twenty-four hours. The first sitting was merely formal; several meetings were held, at which rules and procedure were discussed, and Lavoisier took an active part in suggesting subjects which might profitably be discussed at the next session.

The second session opened in November with a message from the King read by the *Intendant.* The next day being Sunday, the Assembly attended mass, walking in procession headed by the town band from the bishop's palace to the cathedral. It was the custom at this time in such ceremonial processions for the lesser lights to have precedence, those of highest rank bringing up the rear. In this case the town officials went first, then came the representatives of the Third Estate, then the nobles and clergy, who, being considered of equal rank, walked side by side, and lastly the Duke of Luxemburg. Two members of the Assembly officiated at the service, one celebrating mass and the other preaching the sermon.

At the next meeting of the Assembly four committees were appointed which were to deal with, respectively, public good and agriculture, roads and bridges, finance, and taxation. Lavoisier was elected to serve on the first of these committees, which, if one may judge by its title, afforded plenty of scope, and, indeed, it gave Lavoisier the opportunity of raising many topics on which he read papers to the Assembly. His suggestions were usually novel and original, and he soon began to assert himself, both in the committee and in the Assembly itself. His illuminating and closely reasoned papers were listened to with respect, and in practically every case his schemes were adopted as the policy of the Assembly.

One of the schemes which he adumbrated was the establishment of a provincial bank. His avowed object in putting forward this proposal was to assist trade, which he considered, " at least in the greatest number of towns in the kingdom, is restricted and limited by lack of capital." Hence, if the provincial administration abolished all private banks and took over their business, they would have in their hands sufficient funds not only to carry out their own schemes but also to give the necessary fillip to trade by introducing fresh capital.

Another pet plan of his was the setting up of a Provincial Health Insurance and Pensions Fund, " to insure the aged and widows against indigence." He pointed out that there are three stages in a man's life: in infancy he is helpless and depends on the ministrations of others; then comes the time when he can support himself; and finally, in most cases, there is the period of old age, when " there remains to him only the regret of joys he has lost and the sad memory of what has been and no longer is " and when he is again dependent on others. While many when they reach this last stage were cared for devotedly by their sons and daughters, others were not so fortunate; either they had no surviving children, or their family had barely sufficient for their own needs, or, saddest of all, they received nothing but ingratitude from their offspring. Should not the State make some provision for those who had served it? He discussed mortality tables which had recently been published, and pointed out with illustrative examples how quickly a fund could be built up by laying money out at compound interest. He proposed that the Assembly should back this scheme and administer it with the assistance of the Orleans Philanthropic Society, at the same time passing a law that this fund, built up by the contributions of the people, should be " incessible et insaisissable " so that there might be no risk of nullifying the good intentions of the present Assembly. He dwelt on the benefits which were bound to follow from this perfectly practicable idea, and ventured to make a prediction in the form of a question : " Who knows . . . if indeed the peace which the certainty of a happy and undisturbed old age will bring to everybody will not raise the average age of man and diminish mortality?"

Lavoisier's membership of the Provincial Assembly was bringing out his talents as a financier in a remarkable manner. Evidently his experience as a *Fermier Générale* had given him an insight into the mysteries of finance, and he was now brimful of constructive ideas for relieving the burden on those least able to sustain it and for developing the national trade. Another subject he tackled about this time was one of the most unjust of the many iniquitous impositions, the *corvée*, by which the responsibility for the construction and the maintenance of roads was placed on the Third Estate. Lavoisier, in a remarkable memoir presented to the Committee of Public Good and Agriculture, pointed out that the *corvée* had never had legal sanction ; it had been imposed by the *intendants* in 1720, who were then receiving diminished support from a depleted Treasury, and the proprietors of the land, who had formerly been responsible for the roads, were then automatically exempted by reason of their privileges. In 1766 the *corvée* had been suspended by Turgot, at whose fall, however, the suspension was removed. This was the first occasion on which the *corvée* was mentioned in the laws of the country. The reading of this paper caused consternation among a section of the Committee, but was cordially received by others. Vested interests then, as always, decided the issue. The nobles in a panic convened a meeting of their supporters to discuss the situation, and, since they could not find any arguments against the abolition of the *corvée*, they decided to prevent the reading of the paper to the Assembly by making a motion to the effect that there was no occasion for debating the subject. Curiously enough, the Committee of Public Good, even some of the Commons representatives, went back on Lavoisier and declared that they had merely authorised the reading of the paper and that it did not necessarily represent their views. One would think that Lavoisier would have made a fight of it, but, contrary to the advice of some of his friends, he withdrew the paper and it was never read to the Assembly.

Among other subjects which Lavoisier raised were the establishment of workhouses where the poor would be required to make some return in labour for assistance given, a mineralogical map of the province in which some of his own and Guettard's data would be incorporated, and the agriculture and trade of Orleans, which was largely a repetition of what he had already advocated to the agricultural Society of Paris.

After appointing a kind of executive committee of six members, of which Lavoisier was one, the Assembly adjourned. It never met again. The local members of the executive met occasionally till the end of 1790, but from their deliberations and resolutions there was no tangible result. All the reforms that had been advocated and passed by the Assembly were so much wasted effort, unless it may be considered that the momentous proceedings of the National Assembly were influenced to some extent by the experience its deputies had had in the various provincial assemblies.

Meanwhile Lavoisier had continued to carry out his duties as a *fermier générale*. In 1778 Baudon had died, and Lavoisier had been admitted to full membership instead of having only a half interest, as previously. In 1780, when the new contract was drawn up, several changes were made in the organisation of the *Ferme*. The number of members was reduced from sixty to forty, and the State allocated to itself a proportion of the profits when they exceeded a certain amount. Lavoisier was one of those appointed to the new company, and he continued his efforts to secure a less harsh administration of harsh laws and to introduce economies; for example, he suggested that if a uniform tax were levied all over the country all the internal customs houses could be abolished.

One of his proposals, made in all good faith and with the laudable object of preventing smuggling, had a very hostile reception from the public. Lavoisier estimated that about one-fifth of the goods entering Paris were smuggled, which meant a loss not only to the *Ferme*, but also to those honest tradesmen who sold only goods on which the entry tax had been paid. He proposed, therefore, to make Paris a walled city. The idea was not immediately taken up, but it was revived two years later and a start was made with the actual construction. Soon there arose an indignant outcry against this monstrous proceeding. Were the Parisians to be imprisoned by the wicked *fermiers généraux ?* Would these tyrants prevent even pure air from blowing over the city? "Le mur murant Paris rend Paris murmurant," said a wit; and another evolved the doggerel verse:

> "Pour augmenter son numéraire
> Et raccourcir notre horizon
> La Ferme a jugé nécessaire
> De nous mettre tous en prison."

Lavoisier was the special object of attack as the author of the project to imprison the French in their capital. It was suggested that after his death (which ought to be a violent one !) the *Ferme* would erect a statue to his memory on the wall which he had suggested, while his brother scientists in the Academy would blush to think that they had consorted with such a notorious character ! It was all rather silly, but it was treated seriously, and it was actually brought up against him later as one of his many misdeeds.

It is often alleged that men who undertake public work, either local or national, display more generous sentiments in disbursing the money extracted from ratepayers and taxpayers than they do with their private wealth. The allegation can hardly be said to be true in general now, but in France in those pre-

Revolution days there is little doubt that in many cases self-interest was the chief urge that induced men to take up public service. Lavoisier was not of this number. His proposals to the Orleans Assembly show that he was actuated by the highest motive—a love of humanity, and in particular the least favoured part of it, and a sense of justice. But other incidents in his career show him in an even more favourable light. Before he had publicly advocated the spending of large sums of money on agricultural improvements he had himself spent a small fortune in experiments at Fréchines, and he gave the results of his experiments freely to the nation.

His generosity sometimes took a more direct form. He lent money, sometimes without interest and sometimes when there was little or no prospect of his being repaid. After the bad harvest of 1788, which was to play so important a part in the Revolution of the following year, many places suffered great distress. Restrictions were placed on the sale of grain in order to ensure even distribution, and in some market towns soldiers had to be called in to prevent rioting. The town of Blois, with which Lavoisier was connected by reason of his official position as one of the nobility, was very badly hit, and appealed to him for assistance. At once he offered to lend them 50,000 livres without interest to tide them over the difficult period. The municipal authorities were touched by his generosity, but would accept only 32,000 livres, which they hoped to repay by the following August. As far as is known it was never repaid, probably because events made the distress even more severe.

CHAPTER XIII

TRAITÉ ÉLÉMENTAIRE DE CHIMIE

"There are two methods of presenting scientific matter: the first consists in tracing phenomena to the causes which have produced them; the second to suppose the cause and to show that the observed phenomena agree exactly with the supposition. The latter method is rarely followed in the search for new truths, but it is often useful for teaching others; it spares them difficulties and weariness."—LAVOISIER (1788).

At the beginning of 1789 Lavoisier's epoch-making book was published. He had long wanted to systematise the discoveries of the recent period of chemical activity, and the publication of the "Nomenclature" gave him an incentive to do this; in fact, he expressly stated in his introduction to the "Elementary Treatise" that the object of the book was to develop the ideas which had been indicated in the 1787 publication. He had also in mind that all existing books on chemistry were now hopelessly out of date. It was well known that all but the most striking scientific discoveries took some time to filter through to the institutions where science was taught; only those in close touch with the progress of events were familiar with the new doctrines. The result was that the old text-books were being used, and consequently the old theories were still being taught. With the appearance of Lavoisier's book, however, teachers had now a reliable and up-to-date guide by which to regulate their teaching.

A somewhat detailed examination of this great book will lead to a certain amount of repetition, but it will also tend to show to what extent Lavoisier's ideas had developed since his original papers were read to the Academy.

In a lengthy introduction the author made many interesting remarks on chemistry in general, and on the teaching of chemistry in particular. He emphasised that little or no weight should be attached to authority as such, that, where possible, every alleged fact must be verified by resort to experiment. He criticised the text-books then in use in that they usually began by assuming many things which were not at all obvious to the beginner, and which, indeed, should have been led up to by experiment and observation. Tables of affinity, for example, were unintelligible to one coming fresh to the subject, and besides they really consisted of a series of statements which the student had to take on trust. Lavoisier, on the other hand, strongly advocated the principle which has dominated the teaching of science ever since—proceed from the known to the unknown; experiment and observe; then, and then only, form your ideas.

He estimated that it took two or three years to train a chemist. He was all against trying to cram.

He considered that the first year of the course should be devoted to familiarising the ear with the language of the subject and the eyes with its apparatus—a procedure which some science teachers adopt at the present time. *Festina lente* really sums up his advice to teachers. He was careful to warn students that, even at the end of a two or three years' course, they would not have completed their chemical education. Although they might be familiar with all the latest developments, the subject itself was incomplete in contrast with a subject like geometry, which in its main features had not changed for about 2,000 years and seemed unlikely to be further developed, at least as far as the elementary part of it was concerned. But in expecting chemistry to " approach a greater degree of perfection . . . even in our own time " he showed himself to be too optimistic. Could he examine even one of the elementary text-books in use in our secondary schools to-day, he would be amazed at the amount of progress recorded since his death, but at the same time he could not but be gratified at the laudatory remarks made about his own work.

He next went on to discuss one or two points about the subject-matter of chemistry. He dismissed as merely metaphysical any speculation as to the number of the elements, and recapitulated the general plan followed by the authors of the " Nomenclature " in naming the elements and their compounds.

One would expect that Lavoisier would have devoted at least one chapter to the phlogiston theory, but he evidently thought that this would be merely flogging a dead, or at any rate a dying, horse. He excused himself by saying that the book was neither a history of science nor a psychological treatise, but an exposition of the subject as it was then known. He presented it as a straightforward elementary text-book free from the encumbrances of outworn theories. In the introduction to a projected second volume of "Physical and Chemical Tracts," which was never published, he had said that the practice of discussing the history leading up to new ideas merely led to simple facts being hidden in large volumes. In making the decision to avoid this fault Lavoisier probably added to the book's popularity, for people do not like to have their mistakes and shortcomings thrown in their teeth. The effect of the book on the phlogistians, whether recently converted to the new theory or still halting between two opinions, was probably greater than it would have been if Lavoisier had held the old ideas up to ridicule.

Proceeding now to his subject, he began by discussing his theory of gases, giving a closely reasoned exposition of the doctrine of caloric. What makes solids and liquids expand on being heated? He answered that heat insinuated itself between the particles and effected a separation. On cooling the caloric escaped, thus allowing the particles to come closer to one another. But, since we can always imagine that a body can become colder and therefore contract more, the particles can never be as close as possible. Evidently the idea of an absolute zero of temperature had not occurred to him, and in fact it did not emerge till about twenty years later, although his contemporary Charles had already prepared the way for it.

Seeing merits in both the rival theories of heat, he made a half-hearted attempt to combine them by imagining that the molecules of a substance were in motion in caloric. Having said this, however, he made no further use of the kinetic theory except to deduce that there could not be any real bond between the molecules, but only some attractive force which tended to bring the molecules together when caloric was removed. The heating of a body forced caloric into it and was equivalent to introducing a force of repulsion between the molecules, and the physical state of a substance depended on the equilibrium of the two forces. Incidentally, he suggested that light might be a form of caloric, or possibly caloric a form of light.

The next point he considered was the influence of pressure on the change of state. Why, he asked, was not melting ice changed into steam? And his answer was that at this stage the pressure of the atmosphere was greater than the force of caloric; that the latter, while it succeeded in separating the molecules sufficiently for the substance to assume liquid form, was opposed by the external pressure which prevented any further separation taking place until a much greater amount of caloric was supplied. If, he said, there were no atmospheric pressure there would be no liquids, and he found experimental evidence to support this conclusion in the fact that, without any application of heat, ether could be vaporised simply by reduction of pressure.

The chapter entitled " General Views on the Fixation and Constitution of the Earth's Atmosphere " contained some interesting observations which showed that Lavoisier fully realised the influence of temperature on terrestrial conditions. " Suppose," he said, " that the earth were suddenly transported to a much warmer part of the solar system, in the region of Mercury for example, where the habitual temperature is probably much higher than that of boiling water. Soon water and all liquids which vaporise at temperatures below the boiling-point of water, and even mercury, would begin to evaporate." The result would be that the composition of the earth's atmosphere would be very different from what it is under present conditions. On the other hand, he argued, the increase in the amount of gas in the atmosphere would increase its pressure, and this would tend to prevent evaporation. Similarly, if the earth had been very much colder, water would have been known to us as solid rock and air might possibly have existed as a liquid. From all of which he concluded that the classification of substances into solids, liquids, and gases was an entirely artificial one and of no scientific significance.

He next proceeded to the problem of finding the composition of the lower layer of the atmosphere. (He thought that there might be a layer of inflammable gas in the upper air which would account for meteors and the aurora borealis.) It was here that he described in detail his now famous experiment, which he had only outlined in 1777, on the analysis and synthesis of air by the calcination of mercury followed by the decomposition of the oxide. This led him to a discussion of what he called the decomposition of vital air by sulphur, phosphorus, carbon, and metals, and his theory of acids. In all cases where oxidation took place he considered it to be the result of the operation of two forces. "When metals are heated to a certain temperature oxygen has a greater affinity for them than for caloric"; hence the oxygen entered into combination with the metals and caloric was liberated.

Lavoisier next described the experiments by which the composition of water could be established. These were, in their essential features, similar to those described in his Academy papers. One slight change he suggested in the now popular experiment of passing steam over heated iron was to use a glass tube, but there is no record of his having tried this himself. The figures quoted seem to have been merely imaginary numbers designed to illustrate the principle of the process.

After short discussions of the calorific values of certain combustibles, the composition of animal and vegetable matter, and fermentation, he ended Part I with a consideration of bases and salts. Metals he called bases, but not salifiable bases. When a metal was added to an acid an effervescence took place, the first result being that the metal united with oxygen either from the acid or from the water present; then the oxide which was the salifiable base united with the acid to form the salt. Thus it was really oxygen that made possible the action between metals and acids. It naturally followed that since earths such as magnesia, alumina and baryta were salifiable, they were probably oxides of unknown metals—a very shrewd argument.

In Part II he dealt with the elements and their compounds in detail. His ideas about elements were definite and sound. He regarded them as "simple substances, or rather those which the actual state of our knowledge obliges us to regard as such." And again: "We cannot be sure that what we regard as a simple body is really so; all we can say is that a certain substance is the limit at which chemical analysis has arrived and that it cannot be further subdivided as far as our knowledge goes." Working on this definition he drew up a list of known elements, classifying them as follows:

Simple Substances which belong to the Three Kingdoms and which may be regarded as the Elements of Bodies.

Light
Caloric
Oxygen
Azote
Hydrogen

Simple Substances—Non-metallic, Oxidisable, and Acidifiable

Sulphur
Phosphorus
Carbon
Muriatic radical
Fluoric radical
Boracic radical

Simple Substances—Metallic, Oxidisable, and Salifiable

Antimony
Silver
Arsenic
Bismuth
Cobalt
Copper
Tin
Iron
Manganese
Mercury
Molybdenum
Nickel
Gold
Platinum
Lead
Tungsten
Zinc

Simple Substances—Salifiable, Earthy

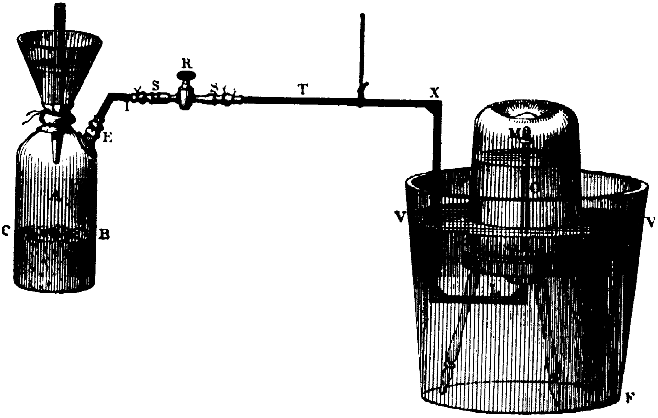
Lime
Magnesia
Baryta
Alumina
Silica

He here repeated his opinion that the earths were probably not simple bodies for the reason already given, and also because they showed no tendency to combine with oxygen, and hence were presumably saturated with it. He frankly admitted that this was purely conjectural, but as it happened, within less than forty years, his tentative and implied prediction was abundantly vindicated, for Davy isolated magnesium in 1800, sodium and potassium in 1807, calcium in 1808, while Gay Lussac and Thénard discovered silicon in 1809 and Wöhler obtained impure aluminium in 1827.

He devoted a section to organic analysis, and then went on to consider the chemical changes into which heat and light entered. After restating his caloric theory he put forward the opinion that light probably combined with certain parts of plants, and that to this fact must be ascribed the green colour of leaves and the various colours of flowers. By way of analogy he pointed out that people who lived in overcrowded houses and those who were engaged in indoor occupations were pale compared with those whose work took them into the open air.

The remainder of Part II was devoted to a detailed description of the compounds known at that time.

Part III was entitled "Description of Apparatus and the Manual Operations of Chemistry." After emphasising that chemistry was an experimental sub-



PREPARATION AND COLLECTION OF GASES.

ject and that proficiency could be attained only by first-hand contact in the laboratory with apparatus and processes, he went on to describe in detail the balance, the hydrometer, the "pneumatic-chemical apparatus," the calorimeter, mortars, furnaces, and the particular apparatus necessary for the analysis of air. Incidentally, he justified the hybrid word *calorimeter*, which had been criticised, saying that "in scientific matters purity of language may have to be sacrificed in order to obtain clearness of ideas." The processes he dealt with included filtration, decantation, solution, gas analysis, fusion, lixiviation, crystallisation, distillation, sublimation, and combustion.

It is of interest to note that he drew a distinction between solution and dissolution, or, as we sometimes say now, physical and chemical solution. When salt was shaken up with water, Lavoisier called the result a solution; when a metal was added to an acid and disappeared, the remaining liquid he called a dissolution. He also noticed that there was some relationship between solubility and liquefaction: gases which were freely soluble were also easily liquefied.

This very inadequate account of Lavoisier's great book will give some idea of its contents, but none of its charm and simplicity. Compared with previous text-books it stood in a class by itself. In point of view, in language, in style, it differed so much from books like Beaumé's, published only twenty years previously, that it has been said that an examination of the books themselves would place them at least a century apart. While Beaumé's book is almost unintelligible to-day, Lavoisier's is quite modern.

The book was an immediate success. Congratulations poured in from all quarters, and soon translations began to appear in several European languages. It was just the book that teachers had been waiting for, and from now onwards courses in chemistry in all institutions where the subject was taught were based on Lavoisier's scheme. If a definite year is to be assigned to the beginning of modern chemistry, then 1789 must surely be that year. Perhaps 1777, the year of Lavoisier's paper "On Combustion in General," marks the real dividing line, or it may be put back to Priestley's discovery of oxygen in 1774, or even to about 1772, when Lavoisier first attacked the problem of combustion, but the years before 1789 were merely a period of incubation, for it was only in that year that the new infant burst forth from its shell upon a scientific world which, somewhat bewildered by the recent upsetting of established ideas, had been waiting for guidance. As Lavoisier himself said later in connection with political events, the chemical revolution was now "irrevocably finished." This masterly exposition did more than the reading of many papers to the Academy to disseminate the new chemical principles; this was a book not only for the learned professor, but also for the beginner. Whereas the Academy memoirs had a very limited circulation, the "Elementary Treatise" found its way all over Europe and even to America.

One curious point about the book was that it added practically nothing to the sum of chemical observations. All Lavoisier's experiments were repetitions with modifications of work initiated by others. In this respect he might be compared with Newton, who, himself adding nothing to the sum of astronomical observations, yet revolutionised the astronomical outlook. Lavoisier made no independent discoveries; he used the mass of facts handed down by his predecessors and acquired from his contemporaries, sifted and collated them, and gave them a new orientation. In this lies his eminent service to chemistry. It almost justifies the much-quoted and much-criticised statement with which Wurtz opened his "Histoire de Doctrine Chimique" (1868): "La chimie est une science française; elle fut constituée par Lavoisier." But this is to minimise too much the work, not only of Lavoisier's contemporaries, but also of his predecessors, all of whom contributed to the revolution of ideas for which he was immediately responsible. Equally extravagant is the claim made by Grimaux in his "Lavoisier," that "toute la science moderne n'est que le développement de l'œuvre de Lavoisier." No student of the history of science contests Lavoisier's right to be included among the great chemists, but it is futile to argue that any particular country or man has done most for the progress of science. A dozen Lavoisiers would not make chemistry a French science. Mechanics is not an Italian science because Galileo was an Italian; astronomy is not a Polish science because Copernicus was a Pole. It is usually impossible to determine just how much a scientist is indebted to others, but in Lavoisier's case it is clear that he owed little to his own countrymen; in fact, he himself deplored his country's decline in chemical achievement during the first half of the eighteenth century.

It is unprofitable, and indeed impossible, to compare such men as Lavoisier and Priestley. Both were geniuses, but in different ways. Priestley's genius lay in his experimental dexterity and the excellence of his observations; Lavoisier's in his ability to generalise. Priestley wandered about in the wood making interesting observations about the individual trees he came across, observations which had never before been made by other wanderers; Lavoisier saw the wood. Without, however, the detailed information that Priestley (and others) was able to bring back from the depths of the wood, Lavoisier would not have been able to visualise the wood as a whole. They explored and discovered; he followed, confirmed, and integrated.

Lavoisier's book thus dealt with facts for the discovery of which he himself was not responsible, though even now he only acknowledged grudgingly his indebtedness to Priestley and Cavendish. It was its simplicity and straightforwardness and the logical point of view it advocated that ensured its popularity. It was a fitting climax to a scientific career which had been devoted to bringing order out of chaos.

CHAPTER XIV

1789-1790

Until 1788 there was little sign of the impending explosion in France. The poorer classes, although cruelly weighed down by their burden of taxation and injustice, had been inarticulate and remained so. They showed a sullen resentment at the state of affairs, but were powerless to alter it. They had their champions, of whom Lavoisier was one, but their advocacy had so far failed to effect any reform. The financial situation had been worsened by two disastrous wars, the Seven Years' War and the War of American Independence, which had impoverished the national exchequer to such an extent that matters were now reaching a crisis. The King was a well-meaning man, but dull-witted and ill-educated. The Queen had a stronger personality, but was given to extravagance. When she found it impossible or inexpedient to attain her wishes by direct means she had no scruples about resorting to intrigue. At the end of the American War the finances of the country were in a parlous state, and the Government proposed measures of economy, but she over-ruled the King's ministers and actually encouraged extravagant Court displays. Calonne, who was Finance Minister from 1783 to 1787, aided and abetted her, and matters grew worse and worse till, in 1788, the Monarchy became bankrupt; the lower and the middle classes had been squeezed dry.

In an endeavour to relieve the situation with which the Assembly of Notables, in 1787, had been powerless to deal, it was decided, on the advice of Necker, a former Finance Minister whom the King had recalled, to summon the States General which had not previously met since 1614. This body consisted of three "estates," the nobility, the clergy and the third estate or commons. The proposal to summon it let loose a flood of literature during the last few months of 1788. One of the chief aspects of the situation which was discussed by the pamphleteers was the relationship between the third and the other two estates. On the previous occasion on which the States General had met the commons had been treated in a most humiliating manner, for they had been outvoted at every turn.

Lavoisier, his political appetite whetted by his recent repast at Orleans, had his own views on this latest move, and he expounded them at considerable length in a memorandum which seems to have been intended for the Prime Minister's eye alone and was never published. He recalled the previous meeting of the States General for the purpose of uttering a warning against following the example of that body which had shown such utter servility to the King that Louis XIV. was able with impunity to disregard its wishes in all matters with which he did not agree. He condemned the maxim, the Bourbon equivalent of the Stuarts' Divine Right of Kings, namely, "A king of France holds his crown by right of God and the sword, and accounts only to God for his conduct." This foundation for the royal vocation, he contended, was dangerous not only for the country, but even for the King himself, for if he held his office by right of conquest he might well be deposed by another whose military resources were greater than his own. No, the wearer of the crown should be the people's choice; he should be the titular head of the country with executive but not legislative power. This, he said, was one of the first matters that must be tackled by the States General, and if this advice was followed it would hardly fail to effect a much-needed reform. "In vain would authority, which in these latter times has yielded much to reason, combat them (the States General); it would expose itself to a fight from which it would not emerge victorious."

He maintained that the States General must be representative, and that it must be constituted in such a way as to procure the greatest good to the greatest number of its constituents. Before they met, the King would have to agree to abandon his right to use the infamous *lettre de cachet* by which a man could be arrested without knowing what charge was made against him, and not to imprison or even to exclude from the council chamber any member of the States General, and to allow reasonable freedom of the Press.

To Lavoisier the question as to how voting should be carried out was not really a matter for discussion. Although there were precedents both for voting individually and by order, surely justice demanded that the votes of the individual members should count in the final reckoning; otherwise it was the nobles and the clergy who made the laws. On the other hand, if the constitution of the States General was to be the same as it had been in 1614, then even individual voting would result in a similar situation, for the first two estates combined had then out-numbered the third by ninety, although they represented only about a quarter of the nation. His remedy for this state of affairs was that the commons should have two-thirds of the representatives and the nobles and the clergy one-sixth each; even then the third estate would not have a representation in proportion to their numbers, but it would give them some semblance of justice.

In all of which Lavoisier's democratic views are amply demonstrated. It must be recalled that he himself enjoyed noble rank with all its accompanying privileges, and his strong advocacy of reform could not therefore have been actuated by envy or hatred; it was merely a result of his first-hand observations of the conditions under which the people lived. He espoused their cause because his humanity and his sense of justice urged him to do so. He had seized the chance at the Orleans Provincial Assembly to suggest measures which could be taken to alleviate national distress; now he saw that the States General, if it were constituted justly, could put those and other reforms into operation. And this was the man who, less than six years later, was sent to the guillotine by the representatives of the people!

In December a royal proclamation gave the third estate the double representation, but still left undecided the question as to whether voting should be by individuals or by estates, and this was the burning question during the next six months.

Lavoisier, who was a member of the nobility of the Blois district, went in February, 1789, to Blois for the election of deputies and the drawing up of the *cahier* or code of instructions for the guidance of the deputies. He was elected secretary of the meeting and was asked to make out a draft of the *cahier*. This gave him yet another opportunity of expressing his democratic sentiments, and in the document which he drew up we get another glimpse of his humanity. It began thus:

"The aim of every social institution is to make those who live under its rules as happy as possible. Happiness must not be reserved for the few, it belongs to all. It is not an exclusive privilege to be called in question; it is a common right which must be conserved and shared; public happiness is a well from which each has the right to draw his own.

"Such are the principles for which the nobility of the Blois district stand at this time when it is called upon by the sovereign to send national representatives. These principles have occupied the minds of all in the drawing up of the *cahier*. May they animate the minds of all the citizens of this great empire! May they secure that united spirit and general agreement which will establish on a firm foundation the power and prosperity of the nation and the well-being of the King and his subjects."

The document then proceeded to discuss in some detail the reforms which were necessary to ensure the happiness of the people. First and foremost came personal liberty, "the first and most sacred of the rights of man." There must be no imprisonment or exile without trial, there must be freedom to write and publish comments on public matters, and the arbitrary powers of the police must be abolished. As for taxation, each should contribute according to his capacity to pay, and taxes should be levied only by the nation through its representatives. The nobility offered to sacrifice all the privileges they had enjoyed and pay their just share of taxation on condition that all the existing taxes were suppressed and a single tax imposed.

The administration of justice, the *cahier* continued, was not a right but a duty, and for the poor it should be free or at least much less costly than it had been. An accused man should be considered innocent till proved guilty as in English law, which was commended as an example which it might be well to follow. As a corollary to the subject of taxation the question of national expenditure was mentioned, and it was urged that the strictest economy was necessary if taxation was to be reduced to reasonable proportions; useless officials should be dismissed, and details of pensions and grants should be made public, together with the reasons for awarding them. Customs within the borders of France should be abolished, a system of national education set up, noble rank should not be purchasable, but given for national services, the clergy should be forbidden to send money to Rome, this being equivalent to an extra tax on the country. Finally, the *cahier* demanded that the States General should not separate before having established a new constitution, and that thereafter it should meet periodically.

After discussion, this *cahier* was adopted by the Blois nobility, and they proceeded to elect their representatives. Lavoisier was chosen as an assistant deputy. It is thought that his noble rank was too recent for him to be elected a full deputy. He returned to Paris in April and resumed his usual round of duties as *fermier générale*, academician, member of the Gunpowder Committee, snatching odd moments in his laboratory.

The States General met in May. They had no leader and no clear ideas as to what they were going to do. They spent six weeks wrangling about matters of voting to the accompaniment of much excitement in Paris and in those provincial towns to which newspapers penetrated. Ultimately the commons declared themselves the sole representatives of the nation, calling themselves the National Assembly, which the members of the other two orders might join if they wished. Three days later, when the King, by accident or design, closed the hall at Versailles where they had been meeting, they repaired to the adjoining tennis courts where they took the famous oath. Re-naming themselves the Constituent Assembly, they began to frame a new constitution with Mirabeau as unofficial leader. The King brought foreign troops into Paris, dismissed Necker, and went back on the concessions he had already granted. This was too much for the long-suffering people, already wearied and excited by the events of the past weeks. They stormed the Bastille in July.

The revolt spread to the provinces; the peasants turned on their oppressors, hunted them like animals, and burned their chateaux. In a month the aristocratic Government had collapsed, and the people had triumphed. The Constituent Assembly produced a new constitution which was modelled more or less on that of the new American Republic, abolished all exemptions from taxation and all the irksome and unjust laws from which the people had suffered.

The times were stirring, but as far as we know, Lavoisier took little active part in the memorable events of that year after the meeting of the Blois nobility. In August, in his capacity of member of the Gunpowder Committee, he was the innocent cause of a riot. Some industrial gunpowder which had been manufactured at Metz was, by order of the committee, to be sent to Rouen and Nantes, because there was no room for it in the Arsenal magazines. As it was passing through Chateau Thierry it was seized by the municipal authorities and sent by them to Paris because they suspected that treason was afoot and that the consignment was destined for the enemies of France. The committee, having a large supply of industrial gunpowder on hand, decided to send this unexpected load to Essonnes for storage. Since no war material was allowed to leave Paris without the permission of the newly appointed Chief of the National Guard, General Lafayette, they sent to him for the necessary permit. He, however, was not available at the time, and the required order was signed by one of his subordinates. The powder was to be loaded on a river boat which was to be guarded by four National Guards, and a beginning was made. The inhabitants of the district, made suspicious by recent events, reported this unusual proceeding at the Town Hall, where Lafayette, ignorant of the order signed by his junior, instead of making inquiries about the matter immediately, ordered that the powder should be returned to the Arsenal. This action was naturally regarded as a confirmation of popular suspicions; rumours spread that the Gunpowder Committee was plotting to take away the means of the town's defence. The four guards were arrested, and once again this much misunderstood consignment of powder arrived at the Arsenal, to the great embarrassment of the committee.

Next day the Commune representatives for the district were summoned, and Lavoisier explained to them exactly what had happened. In order to calm the excited populace two men were appointed to make an inquiry. They went to the Arsenal, found everything just as Lavoisier had said, and signed a report to the effect that there had been no irregularity. It looked as if the affair had ended, but the mob was not satisfied; they demanded the arrest of Lavoisier and another member of the committee. These two were taken to the Town Hall, where they had no difficulty in exculpating themselves. When the crowd learned that permission had really been given to send the gunpowder out of Paris they turned their attention from the Gunpowder Committee to the officer who had signed the order, but he, having been warned in time, managed to escape. Gradually the true state of affairs became known, and in a few days the incident was forgotten—at least it appeared so—but it cropped up again as we shall see.

In September Lavoisier assumed yet another duty when he consented to become a member of the Paris Commune which had been set up in July. There was now in his career a decided drift towards politics and away from science. The amount of time he could devote to research was beginning to depend on the amount of time he could spare from his political and administrative activities, and as the latter increased under the new *régime*, so the former diminished and became spasmodic.

October saw the impudent parade of plenty at a banquet at Versailles and its sequel, the Women's March. The bad harvest of the previous year had caused famine and distress, and the lavishness of the banquet was more than human beings, especially hungry and revolutionary human beings, could stand. The King was taken forcibly to Paris and was thereafter virtually a prisoner in the Tuilleries.

Although the people had triumphed, the financial plight of the nation was as bad as ever. Many of the nobles had fled the country shortly after the attack on the Bastille, and although they were not now exempt from taxation, they were not there to be taxed. The Church, however, owning a fifth to a quarter of the soil, was wealthy in land if not in cash, and the Assembly hit upon the really ingenious idea of issuing notes, called *assignats*, on the security of the Church lands; each note represented an actual plot of ground. This stroke of genius relieved the situation, and the country was again solvent, but in the fulness of their success the Assembly made the mistake of overdoing it, with the result that as the notes came from the printing press in increasing numbers, their value after a time began to depreciate until in a year or two they were practically worthless. Lavoisier, in a paper read to the '89 Club in 1790, issued a warning that this would happen unless the production of *assignats* was limited. Lavoisier was consulted by the Government on one of the technical points in connection with the issue of these notes. He was asked to give his advice as to the best means of preventing their forgery. This necessitated investigations into the kind of paper and the quality and colours of the inks to be used and the best methods of making the plates from which they were to be printed.

Lavoisier, who had always been a friend of the oppressed and who had striven under the old system to reform the organisation of the *Ferme Générale* and to improve methods in agriculture, was well satisfied with the results of the Revolution so far, but he was rather anxious about the future of the country. In a letter to Franklin at the beginning of 1790 he said: " We regard it (the Revolution) as finished and irrevocably finished. There is still a weak aristocratic party which vainly tries to make a show of strength. The democratic party, on the other hand, is the more numerous and includes the most intelligent and best educated of the people. The moderates who have kept cool during the general effervescence think that circumstances have carried us too far; that it is a pity to have had to stir up the people; that it is imprudent to place in power those who ought to obey, and that it is to be feared that the new constitution is meeting with opposition from those in whose favour it was made."

Lavoisier was also considerably worried about the extent to which the march of events had interfered with his scientific work. In a letter to Black, written in 1790, he said: "The plight of public affairs in France for the last year has slowed up the progress of science for a time and has taken savants away from their cherished occupations; but we must hope that peace and prosperity will follow the troubles which have befallen us and which were inseparable from a great revolution."

If Lavoisier's opinion may be taken as representative, it is evident that the people of France had no inkling as to what was yet in store for them. The worst was over, they thought, and they could settle down again now that they had gained their ends and look forward to better days ahead. Their respite was a brief one.

The year 1790 was a quiet one politically, but for Lavoisier it was crowded with many and varied tasks, so much so that laboratory work, which he had planned and was anxious to get on with, had to be indefinitely postponed. He particularly wanted to investigate the means whereby plants and animals were able to assimilate mineral matter and change it into material which was liable to ferment, decay and burn. He suggested that since these processes returned to the mineral kingdom, the substances which had been assimilated from it, the growth of plants and animals might simply be the reverse of combustion and putrefaction. But he had not time to follow up the idea.

He was appointed a member of the Money and the Health Commissions. He and another were asked to test a process designed to prevent gun-barrels from rusting. The Vagrancy Commission turned to him for help in devising means of making hospitals more hygienic. He took upon himself, too, the task of championing the interests of the Academy, for during the inevitable confusion involved in the change of Government certain financial obligations previously undertaken by the Government were not now being implicated. This was causing hardship to some members of the Academy who depended, partly or wholly, on their remuneration as academicians. By his persistence and tenacity in tackling deputies and Government officials he succeeded in having most of the grievances remedied.

Besides all these extra duties and the administrative work which had been part of his life for many years, he found time to attend the meetings of the '89 Club. The objects of this Club were to propagate the principles of a free constitution and to cultivate the social art, and among its members, 400 in number, were found many distinguished men in all walks of life, including many of the moving spirits in the Revolution. Occasionally papers on topical subjects were read by members, for example, Lavoisier's papers on the *assignats*. After an existence of only about two years the club began to be suspect, and later, to have been a member was almost sufficient to condemn a man as a counter-revolutionary.

Some details must now be given of a paper read by Lavoisier to the Academy during the period under review. It dealt with respiration, and was in some respects an important contribution to the knowledge of the subject. The work was done in collaboration with Séguin. After recapitulating the main points of the new chemistry, the authors of the paper proceeded: " Now that these truths have stood the test of time and have been confirmed by the agreement of nearly all European physicists and chemists, we can say with confidence that in chemistry there is nothing that is not founded on obvious proofs." As these " truths " included the doctrine of caloric and the oxygen theory of acids, the relative nature of scientific truth is once again exemplified.

Previous knowledge of the subject of respiration they summed up thus: " Respiration is merely a slow combustion of carbon and hydrogen which is similar in every respect to that which occurs in a lighted lamp or candle, and from this point of view animals that breathe are really combustible bodies which burn and are consumed." And just as a lamp had to be replenished with oil, so animals died if they were not supplied with fuel in the shape of food. Some of the similes used by the poets, they remarked, contained a truth whose significance the poets themselves did not fully realise. " One might say . . . that the torch of life is lit when a child breathes for the first time, and that it is extinguished only at death."

The paper then went on to describe some new experiments which had been recently carried out. Experiments with guinea-pigs showed that there was no observable difference in respiration if the animals were placed in an atmosphere consisting of one part of oxygen to four parts of hydrogen by volume instead of air, which indicated that hydrogen was not poisonous and that azote took no part in the process of respiration.

The volumes of air breathed by a young man while at rest and again while he was engaged in some physical labour were measured, and observations were simultaneously made on the temperature of the blood, which was found to remain constant, and on the pulse and the rate of breathing, which showed remarkable variation. The actual results, which the authors realised depended on the age, the state of health, and the occupation of the subject, seemed to them to show that the increase in the pulse was proportional to the amount of work done as long as the subject was not pushed to the limit of his strength, and that the quantity of vital air consumed was proportional to the product of the amount of inspired air and the pulsation. They suggested that this method of investigation might be applied to the comparison of forces which seemed to be incomparable; for example, measurements might be made so as to find out the physical equivalent of an orator's speech, a musician's performance, a philosopher's thinking, and an author's writing. Even now, however, the ratio of the amount of the energy expanded by the black-coated worker to that expended by his grimier and more muscular colleague has not been determined, and the debate continues.

The paper then proceeded to a piece of moralising such as is not usually found in academic productions, which was no doubt largely a gesture to the times in which they were living. Why does the poor man who works hard require more food than the man of leisure who, able to buy as much food as he wishes, needs less of it? The fault lay not with nature, but with the organisation of society. "Let us bless philosophy and humanity which unite in promising us wise institutions which will tend to equalise wealth, raise the price of labour, assure it of a just reward, and present to all classes of society, and particularly to the poorer classes, more enjoyment and happiness."

After this digression the paper resumed its main tenor and attempted to account for man's power of adjusting himself to his physical environment. Lavoisier and Séguin suggested that in cold climates, since the air was denser more of it was taken into the lungs at each breath, and hence more caloric was liberated by the internal combustion, and this counteracted the low surrounding temperature, keeping the temperature of the body constant. This temperature they took as 32° R., which is equivalent to 104° F.; this indicates either careless observations or, more probably, an inaccurate thermometer. Another cause which tended to maintain this constant body temperature was the fact that in cold regions there was less transpiration, and therefore the cooling effect which this produced was considerably diminished. On the contrary, in a warm climate the conditions were exactly opposite; less caloric was produced because of the smaller density of the air and the cooling effect of transpiration was greater. The adjustment of the human body to the conditions of an active or a sedentary life could be explained in a similar manner.

Finally, the whole matter was summed up; the animal machine was controlled by three regulators—respiration, transpiration, and digestion, which maintained an equilibrium in the body. Disease resulted from the upsetting of this equilibrium and death from the inability of nature to restore it.

In April, 1790, in a paper dealing mainly with transpiration, the same two authors described experiments in which they had attempted to separate the effects of respiration and transpiration by making the subject of the experiment wear a garment made of oiled silk which was impenetrable to air and moisture.

CHAPTER XV

PERSONAL ATTACKS

At the beginning of 1791 France had completely recovered her equilibrium and had settled down to consolidate the position gained. The King, at the anniversary of the taking of the Bastille, had accepted the new constitution, and it seemed that the country could now look forward to a period of increasing prosperity. Below the surface, however, there were undercurrents of suspicion, jealousy and intrigue. The Queen had never accepted the humiliating position into which the monarchy had been thrust, and she was in communication with the *émigrés* and with her royal relations in Austria, and the attempted flight of Easter, 1791, and that of the June following which was within an hour of success, were the products of the Queen's initiative and enterprise.

On the other hand, the new Government and its supporters were on the alert for any sign of a counter-revolutionary movement. A watch was kept on individuals and on corporate bodies for any suspicion of reactionary tendencies, and those who had held high positions under the former *régime* were the special objects of supervision. It would hardly have been expected that Lavoisier would be an object of attack, in view of his avowed democratic principles and his services to science and to the nation, which were universally applauded, but even he did not escape suspicion, and, in fact, direct denunciation. True, the first attack came from what was then an insignificant quarter and arose out of private envy and jealousy, but it sowed the seed of future trouble. It came from Marat, who at that time had not taken any prominent part in national affairs, though his influence was beginning to be felt. Marat considered that he had some scientific ability. In 1780 he had published a paper entitled "Physical Researches on Fire," in which he had proposed a theory of combustion which was opposed to that of Lavoisier. He had proved, to his own satisfaction, that when a lighted candle was placed in an enclosed space it was extinguished because of the increased pressure due to the expansion of the air. This and other crude ideas with little experimental backing he had put forward in all seriousness, and it had fallen to the lot of Lavoisier to contradict a report that Marat's views had the support of the Academy. This he had done in a curt and unceremonious manner, and Marat had never forgiven him for this casual treatment. He had nursed his resentment for eleven years, and now he saw his opportunity to hit back. He issued a miserable pamphlet, in which he traduced eminent members of the Academy, accusing them of having used for their own ends money voted for the study of hydrometry. But it was Lavoisier who was the chief object of attack; he described the foremost chemist in Europe as "the putative father of all the discoveries which are noised abroad; since he has no ideas of his own he appropriates those of others; but being incapable of appreciating them, he abandons them as lightly as he adopts them, and he changes his systems as he does his shoes. In the space of six months I have seen him pick up in turn the doctrines of fire principle, igneous fluid, latent heat. In a shorter space I have seen him infatuated with pure phlogiston and ruthlessly denouncing it. Some time ago, following Cavendish, he found the precious secret of making water with water. Then, having dreamt that this liquid is only pure air and inflammable air, he changed it into combustibles. If you ask me what he has done to be so much extolled I reply that he has secured an income of 100,000 livres, that he has suggested making Paris a vast prison, and that he has changed the term acid into oxygen, phlogiston into azote, marine into muriatic, nitrous into nitrite and nitrate. These are his claims to immortality. Proud of his accomplishments, he rests on his laurels while his disciples praise him to the skies." To anyone who was acquainted with Lavoisier's views and had studied his evidence, these statements were not only travesties of the truth, but scandalous and insidious lies, insidious because they contained a sufficient number of scientific terms to impress the ignorant with the author's knowledge.

Like all good propagandists Marat was not content to leave the matter after having only once bruited it. A political phrase, an advertising slogan, or a libel if repeated often enough begins to have a true ring. He returned to the attack when he acquired a periodical called *L'Ami du Peuple*, using its pages to " expose " Lavoisier. " I denounce you," he wrote, " the

Corypheus of the Charlatans, Sieur Lavoisier, son of a land-grabber, chemical apprentice, pupil of a Genevese stock-jobber, *fermier générale*, régisseur of gunpowder and saltpetre, administrator of the Discount Bank, Secretary of the King, Member of the Academy of Sciences. Would you believe that this insignificant man, who enjoys an income of 40,000 livres and who has no other title to public recognition than to have put Paris in prison, to have cut off its supply of air by a wall which cost the poor people 33 millions, and to have transferred gunpowder from the Arsenal to the Bastille on the night of 12th and 13th July, schemed like a demon to be elected an administrator of Paris. Would to heaven he had been strung up on a lamp-post on the 6th of August; the electors of La Culture would not have had to blush for having nominated him."

The very vigour of this diatribe really carried its own condemnation. Those who knew Lavoisier and his wonderful record, both as scientist and as administrator, could well afford to ignore this crude attempt to belittle him in the eyes of the public, but for those who had only a vague idea or none at all as to what exactly Lavoisier had done to earn all the encomiums which had for years appeared in the Press, Marat's denunciation in those times of mutual suspicion undoubtedly made Lavoisier a marked man. Whether or not his fate would have been different if he had not had Marat for an enemy it is difficult to say; probably he would not in any case have escaped the fate of his fellow-*fermiers*.

Marat's reminder of the incident of August, 1790, when the attempt to send gunpowder out of Paris led to a riot, turned public attention to the Gunpowder Committee, but surely if ever a committee had fulfilled the purpose for which it was created, this committee had done so and would therefore be immune from attacks on any ground, whether political, economic, or administrative. But it is notorious that public gratitude for local or national service is given grudgingly and is soon forgotten, and criticism, reasonable or unreasonable, is the lot of him who gives his time and talents to public work. Some of the actions of the Gunpowder Committee, individually and collectively, began to be called in question, and their alleged shortcomings were the subjects of attack. They took up the challenge. Lavoisier drew up a long statement, which was issued with the approval of the Committee. It was a dignified vindication of the Committee's actions and opened thus: "Public officials entrusted with a national and a difficult service must always have the confidence of the people and be supported by the respect of their fellow-citizens; the more unreserved is their devotion to the nation and the more they are exposed to the dangers inseparable from their duties, the more sensitive they are to injustice and the greater importance they attach to keeping from public opinion the damaging impressions of their work which some try to spread." Hence, Lavoisier went on to say, since the Committee had been and was being attacked it must do what it could to rehabilitate itself with the public.

He pointed out what the Committee had accomplished in increasing the supply of gunpowder, in improving the methods of manufacture, and in reducing the cost to the State. He explained the transfer of gunpowder from the Arsenal to the Bastille in July by pointing out that the Committee was simply carrying out the orders of those who were authorised to give those orders. He showed also, as he had done at the time, that the August incident had quite a simple explanation and reminded the public that there had been nothing surreptitious about the attempt to send gunpowder out of Paris, since it had been loaded on the boat in broad daylight. The statement ended on a personal note, in which Lavoisier set down the individual qualifications of the members of the Committee and the parts they had taken in academic and economic affairs.

The pamphlet ran to sixteen quarto pages, but whether it put an end to the gossip and slander is not recorded. Such attempts at exculpation, though they may allay public suspicion for the moment, usually leave behind the germs of future trouble and favourable conditions will foster their growth, so that the convenient public memory recalls the baseless charges but not the defence of the accused. As far as Lavoisier himself was concerned, his connection with the *Ferme Générale* was to be quite sufficient in itself to bring about his downfall.

CHAPTER XVI

NATIONAL SERVICE

THAT Marat's attacks did not get home is indicated by the demand for Lavoisier's services in various capacities by the new Government. Even after Marat rose from comparative obscurity to be one of the leaders of New France Lavoisier retained official confidence. This is probably explained by the fact that Marat's object was mainly to discredit him as a scientist, and scientists had not yet been included in the category of those of whom the country had no need.

The first national reform in which Lavoisier had a direct part was that of the weights and measures. The multiplicity of standards in France and the consequent inconveniences had many years ago been pointed out by the Academy of Sciences, which had often advocated the adoption of national standards. Some of the *cahiers* had mentioned the matter, and as a result of a discussion in the National Assembly the Academy was requested to make recommendations as to a new set of standards based on some unit which would be acceptable to other countries. They were advised to obtain the co-operation of the Royal Society of London, but this body, fearing possibly that they would run the risk of being suspected of harbouring revolutionary tendencies, received the proposal in so half-hearted a manner that the Academy decided to proceed alone.

A committee consisting of Borda, Lagrange, Laplace, Monge, and Condorcet was appointed to plan the work and apportion duties, and they reported in March, 1791. They suggested that the unit of length should be based, not on the length of the seconds pendulum, as had been proposed, since this would vary from place to place, but on a definite fraction of the earth's meridian, a suitable fraction being one forty-millionth. They reported also that they had set up several sub-committees to deal with the various parts of the work involved, one to measure the distance from Dunkirk to Barcelona, one to draw up comparative tables of the various weights and measures in use in the different districts in France, and one to determine the weight *in vacuo* of a certain volume of distilled water at its freezing-point. Lavoisier was a member of this last sub-committee, and had Haüy as colleague.

The National Assembly voted a sum of 300,000 livres to defray the expenses of the investigations, and Lavoisier was asked to act as secretary and treasurer, which post ultimately involved a considerable amount of correspondence, both with the members of the sub-committees and with the officials of the National Convention, as the ruling body came to be called.

Lavoisier had earned the reputation of being a shrewd and upright financier. When, in September, 1791, the nation's purse was transferred from the King's to the nation's pocket and a committee of six was appointed to take charge of it, Lavoisier found himself a member. This, indeed, was an honour, and one that must have been gratifying to him after the disgraceful manner in which he had recently been treated by a certain section of the community. It was no doubt a gesture to public opinion that he refused to accept any salary for his services in this capacity, saying that his emoluments as a member of the Gunpowder Committee sufficed for his humble needs and tastes. This looks very like playing to the gallery, for by this time Lavoisier was quite a rich man, but we cannot blame him for taking the opportunity of trying to rehabilitate himself with those who might have been influenced by the calumnies which had been piled on his head.

To give him his due, however, his reason for offering his services gratuitously may have been his desire to retain his membership of the Gunpowder Committee, which had become almost a hobby with him instead of a duty, and which entitled him to reside at the Arsenal. Ever since he was appointed to the Committee he had taken a keen interest in its work, and he was not a little proud of its achievements. He had devoted a great deal of his time to the problems connected with the supply of saltpetre, the optimum proportions of the ingredients of gunpowder and their proper mixing, and the organisation of the whole business.

He received a verbal assurance that, although he might not be able to discharge satisfactorily the duties of both posts, he would be permitted to retain, nominally at least, his membership of the Gunpowder Committee. If this idea had been that service given freely to the Treasury would ensure that this promise would be fulfilled his tactics failed to accomplish their object, because in September the National Assembly, in the course of their deliberations on national services, decided to relieve Lavoisier of his responsibilities as a member of the Gunpowder Committee in view of the onerous nature of his duties at the National Treasury and on the Commission of Weights and Measures. Lavoisier immediately lodged a protest, and in a letter to the responsible Minister he recalled the verbal promise and asked at least to be allowed to continue his residence at the Arsenal where, at his own no inconsiderable expense, he had established his laboratory. This request was granted.

At the Treasury Lavoisier had ample scope for his financial talents; he was declared to be the most useful member of the committee, and he assumed or was given a large share of its work. He introduced simple methods of book-keeping, and under his guiding hand so strict an account was kept of income and expenditure that he knew exactly the state of the national bank-book day by day. Towards the end of the year he published a brochure entitled "The State of French Finances on the First of January, 1792," in which he set out clearly the financial condition of the country and furnished all the data necessary for the preparation of the next Budget. He issued this anonymously because he did not want attention to be taken from the contents to its author, whose name might recall the previous attacks on him.

Towards the end of 1791 he was asked to accept the post of treasurer of the Academy, and in January, 1792, he was appointed a member of the Advisory Board of Arts and Crafts which had been set up a few months previously to advise the Government on useful inventions.

The increasing number of his public duties had the inevitable result of seriously curtailing his scientific work; in fact, about this time he could hardly snatch even an hour in his laboratory, and he was not at all happy about it. While he was glad to be able to serve his country in any way that lay in his power, he felt that the undoubted success he had attained in research as attested by scientists all over Europe should be followed up, and he had in mind several scientific problems mainly physiological which he was anxious to study. He was feeling the strain, too, of all his public duties, not only the physical strain, involved in attendance at meetings, in clerical work and in organisation, but also a certain amount of mental anxiety about the trend of events. The Legislative Assembly, which had replaced the National Assembly, contained certain elements which did not make for peace. Although the King had accepted the constitution, a strong and growing Republican Party, the Jacobins, had arisen, and their leaders, Robespierre, Danton, and Marat, began to dominate the Assembly. Mirabeau, whose influence as a constructive statesman might have carried weight, had died in 1791. Paris was full of unemployed, partly due to the fact that the parasitic trades had necessarily declined since the flight of the nobles. These same nobles were in communication with the

King, and war with Austria seemed inevitable. All this, coupled with the still unsatisfactory condition of the nation's finances, could, in his opinion, lead only to disaster. In this pessimistic frame of mind he resigned his post at the National Treasury to the great regret of his colleagues, who put it on record that his distinguished and unwearied activity had contributed in no small measure to any success that had been attained.

Relieved of these duties, he now re-assumed his place on the Gunpowder Committee, but, finding that the members of this Committee were now regarded with suspicion, he immediately severed his connection with it, but undertook to continue to give it his assistance unofficially. This voluntary resignation involved his removal from the Arsenal, which he regretfully quitted in August, 1792. He found a suitable residence in the Boulevard de la Madeleine. He must have received a hint as to what was about to take place, or else his reading of the trend of events was remarkably accurate, for three days after he left the Arsenal the police arrived there to put all papers under seal and to arrest the three members of the Gunpowder Committee, one of whom, old and infirm, committed suicide rather than submit to the ignominy of arrest.

Perhaps the greatest political honour that was accorded to Lavoisier was the invitation to become Minister of Public Revenue. His experience as a *fermier générale*, his published opinions on national taxation, and the financial acumen he had displayed at the National Treasury no doubt weighed with the

King and the Government in offering him this post, but Lavoisier, disquieted at the state of the country and anxious to return to the delights of scientific research, firmly but courteously declined the honour. The letter, dated June 15th, 1792, in which he conveyed his decision to his sovereign, was as follows:

"Sire,—It is neither because of pusillanimous fear far removed from my nature, nor of indifference concerning the public weal, nor even of a feeling of inadequacy of my powers that I am constrained to refuse the mark of confidence with which Your Majesty wishes to honour me in offering me the Ministry of Public Revenue. Witness as I have been during the time I have been attached to the National Treasury of Your Majesty's patriotic sentiments, of your tender solicitude for the welfare of the people, of the inflexible correctness of your principles, of your unvarying integrity, I feel more strongly than I can express what I am losing in foregoing this opportunity of becoming the mouthpiece of your sentiments to the nation.

"But, Sire, it is the duty of an honest man and citizen not to accept an important post unless he has some hope of fulfilling its obligations in every respect.

"I am neither Jacobin nor Feuillant. I am a member of no society or club. Accustomed to weigh everything in the balance of my conscience and my reason, I could never consent to subordinate my opinion to any party. I have sworn in the sincerity of my heart fidelity to the constitution which you have accepted, to the authority constituted by the people, to you, Sire, who are the constituted King of the French, to you whose misfortunes and virtues are not sufficiently realised. Convinced as I am that the legislative body has gone beyond the limits laid down by the constitution, what could a constitutionalist minister do? Being incapable of compromising his principles and his conscience he would invoke in vain the authority of the law to which all Frenchmen are bound by solemn oath. The resistance he might advise by means which the constitution allows your Majesty would be represented as a crime; he would perish a victim of his duty and the very inflexibility of his character would become a source of new misfortune.

"Sire, allow me to continue to consecrate my labours and my life to the service of the state in more obscure positions where I can render services perhaps more useful and probably more lasting. Devoted to public education, I shall seek to enlighten the nation about its duties. Soldier and citizen, I shall bear arms for the defence of my country, of the law, and of the safety of the permanent representative of the French people.

"I am, with deep respect, of Your Majesty, Sire, the very humble and obedient servant."

Whether Lavoisier's exaggerated statement about the King's virtues was merely the characteristic gushing of a Frenchman or a diplomatic move to retain the royal favour, or an honest opinion we have no means of knowing. The very day on which this letter was written Louis was laying up fresh trouble for himself by insisting on his right to veto measures passed by the Legislative Assembly, and five days later the Palace of the Tuilleries, where the Royal Family was living in virtual imprisonment, was stormed. Two months later a similar attack started by Danton resulted in the decimation of the Swiss Guard which was followed almost immediately by the notorious September massacres for which Marat was mainly responsible. Then the National Convention which had replaced the Legislative Assembly declared France a republic. The *émigrés* were banished and the King was to be tried.

Lavoisier, glad to escape even for a short time from the political excitement and turmoil of the French capital, went to Fréchines for a holiday. There, among his tenants and in those peaceful country surroundings, he found fresh bodily vigour and mental relaxation. As it turned out, this was his last visit to his country residence. He returned to Paris at the beginning of November and devoted himself almost entirely to the work of the Advisory Board of Arts and Crafts, the Commission of Weights and Measures, and the routine work of the Academy.

CHAPTER XVII

NATIONAL EDUCATION

It has been already mentioned that in September, 1791, Lavoisier was asked to serve on the Advisory Board of Arts and Crafts which had been set up to advise the Government on the utility to the State of inventions. Actually its functions became very much wider than this, and it came to be recognised as a kind of consultative body to which all sorts of matters were submitted for expert advice. It was a strong committee composed of men each eminent in his own sphere and all drawn from the principal learned societies in Paris. About half of its thirty members represented the Academy of Sciences, and it met in the Academy rooms at the Louvre.

For more than two years Lavoisier took part in the labours of the Board, and, being a willing horse, he carried on his shoulders a large share of its work. As he had by this time severed his connection with the Treasury and the Gunpowder Committee he had time to devote to this work. Among the reports for which he was responsible were those on claims for rewards for the improvement of paper-making and for a process for extracting oil from grape-stones. Another matter on which he was eminently qualified to pass judgment was the work of a man called Dupain Triel.

This man was a geographer and had corresponded with Guettard and Lavoisier during their early journeys. When Guettard was too old and Lavoisier too busy to continue the work of making the series of geological maps they had planned, he had carried on the task in collaboration with another.

Lavoisier's crowning achievement, however, in connection with the Advisory Board was his production of a scheme of national education. He was no educational faddist, nor had he exaggerated ideas of the importance of his own favourite subject. His outlook was statesmanlike, and his incidental comments on the mental make-up of children and on methods of teaching showed that he was a psychologist of no mean order. The scheme was an ideal one, and probably he himself did not dare to hope that it would be adopted immediately or in full; as a matter of fact, many of its features, although obviously desirable, have not yet found a place in the curricula of our schools.

In the course of some general remarks Lavoisier hazarded the opinion that only education could consolidate the results of the Revolution and raise the prestige of France; in other words, to use a modern phrase, education was a good investment. A child's brain, he continued, was blank but receptive, and it was the duty of the State to see that the impressions it received were of the best kind. Hence it followed that education should be free to all without regard to social position. He drew attention to the fact that while those who were destined to occupy public posts now received a liberal education there were no schools which prepared boys for what might be called the lower walks of life. " The arts," he said, " include work of all kinds . . . the aim of public education is therefore to make artisans." He did not mean by this that education was to have a vocational bias ; his suggested curricula show that he was thinking of the artisan not so much as a workman, but as a man.

He proposed the establishment of four kinds of schools—primary schools, elementary arts schools, institutes, and *lycées*. A child would enter the primary school at the age of six. The education given would follow the natural development of the child who, during the early stages, would deal mainly with concrete objects and pictures, " so that the idea will never be separated from the word." He would gradually be introduced to reading, writing, and elementary arithmetic, general and natural history. There should be frequent change of subject, so that the child should not be unduly fatigued, and where possible the subjects should be taught through the medium of games and recreations. At a later stage the principles of citizenship should be introduced in the form of information on the rights and duties of man, and some elementary ideas about trade and commerce should be given. The child should be taught how to use a dictionary, a contents table, maps and plans. While girls would receive instruction in sewing, cookery, home management, and the care of domestic animals, boys were to have practice in the use of the ruler, compasses, and the balance, receive instruction in gardening, and learn something of local industries, the last being supplemented by visits to neighbouring factories and workshops.

Lavoisier had very advanced ideas on the internal administration of the school. He advocated democratic organisation throughout; for example, punishment for a fault should be inflicted only after the delinquent had been found guilty by a jury chosen from among his fellows. Rousseau's influence is seen here.

Lavoisier fully realised that his curriculum was an ambitious one and that it could not be put into practice all at once; he was legislating for the future. To begin with, the supply of teachers would have to be greatly increased, and they would have to be specially trained. Text-books, too, were few in number, and in many cases poor in quality and out of date. The immediate tasks therefore were to train teachers, to ensure a supply of suitable text-books, and to begin to build schools.

On completion of the primary school course pupils were to be transferred to a secondary school. This would normally happen at about the age of eleven. This proposal sounds familiar to modern ears; it is hard to realise that the idea recently mooted about transference at the age of "eleven plus" was suggested about 150 years ago. The secondary schools were to be of two types, the Institutes, corresponding very roughly to our English secondary or grammar schools, and the Elementary Arts Schools, corresponding to our central or "modern" schools. In the latter the education was to be of a general nature, extensive rather than intensive. This type of school would be an entirely new departure; "there is no example of its kind in existence because no nation has yet troubled about the education of the most industrious of its people." He suggested that there should be one such school in the chief town of each district.

Grammar was to have an important place in the curriculum of these schools; Lavoisier emphasised the necessity of teaching pupils to express their ideas clearly and precisely. Boys would study French law and constitution, the elementary principles of political economy and commerce, drawing and perspective, geometry and general science, including experimental physics and chemistry, natural history and machines. The course for girls would offer design, sewing, cookery, household management, care of the sick, history, and local geography.

In connection with these schools he proposed an experiment in adult education. According to his scheme, the teachers were to hold classes which would be open to all on Sunday evenings for the discussion of ethics and the arts. It is noteworthy that he did not make the mistake of suggesting some academic subject for these Sunday evening study circles as many educationists would have done. Whether the subjects he actually proposed would have attracted many students is, of course, a moot point.

The curriculum of the other type of secondary school, the Institute, was to be on traditional lines, but extended to include many aspects of life which then did not find a place in schools. Pupils would be allowed a choice of courses which would be made up from the following list of subjects: Grammar, languages, ancient and modern, composition, poetry, design, music, history, geography, psychology, logic, political economy, commerce, French law and constitution, natural history, experimental physics and chemistry, mathematics, astronomy, anatomy, surgery, medicine, agriculture and gymnastics. It would be a very efficient (and very costly) school which would provide this fare for its pupils ! Lavoisier here allowed his enthusiasm and passion for thoroughness to outrun his judgment. He was very lavish, too, in the matter of equipment ; each school was to have a well-stocked library, models of machines, a garden, and a varied assortment of scientific instruments.

Finally, the educational system was to be rounded off by the establishment of twelve *lycées nationaux* or national colleges in which the subjects begun in the secondary schools would be studied more intensively.

As a kind of supplement to his scheme Lavoisier proposed that four *National Societies for the Advancement of Science and the Arts* should be set up, which would meet once a month to hear announcements of new discoveries and which would serve the purpose, among others, of keeping teachers up to date. There would be one for mathematics and the physical sciences, one for the application of science to the arts, one for moral and political science, and one for literature and the fine arts.

Organised education in France in the eighteenth century was a very patchy affair. In some districts it was comparatively efficient, but in others educational facilities were very restricted. Thus Lavoisier's magnificent, too magnificent, scheme was little short of revolutionary; in fact, it sounds advanced even to modern ears. The break at the age of eleven, the width of the curriculum, the methods of presentation, and the part taken by the pupils in the maintenance of discipline have a familiar ring about them to those who are interested in modern educational discussions. In some respects Lavoisier was ultra-modern; his idea of linking up the schools and colleges with the learned societies was undoubtedly good, and is a proposal well worthy of consideration at the present day; it would benefit both the schools and the learned societies. It is noteworthy that he made no mention of examinations or certificates. This would hardly be an oversight on the part of a man who had envisaged the whole organisation in all its details as he had done, and we are therefore left to assume that promotion from one class to the next and from one type of school to another was a matter for the teacher's sole discretion.

The one serious omission was his failure to consider the financial aspect of his project. Although France had succeeded in avoiding absolute bankruptcy, the national Exchequer was still in a depleted condition. The capital expenditure necessary for the building and equipping of such a large number of schools could not have been contemplated at that particular time. Lavoisier must have realised this, although he did not mention it, and probably he intended his scheme as an ideal to be approached gradually.

CHAPTER XVIII

THE SUPPRESSION OF THE ACADEMY

When Lavoisier took over the treasurership of the Academy at the end of 1791, the accounts were in a chaotic state owing to the long illness of the former holder of the office. Government grants for 1790 had not yet been paid, and this necessitated correspondence and interviews with the Minister of the Interior. One academician, an old man of seventy-seven, Lemonnier by name, was in ill-health and his pension of 500 livres had not been paid. Lavoisier interested himself in him, and persuaded the Academy to come to his assistance. Grants which had been made by the Academy to individual members for research work had been allowed to fall into arrears; Lavoisier saw that they received the money to which they were entitled. In these and other matters Lavoisier was indefatigable and showed a terrier-like persistence in his efforts to achieve his ends. Ministers were pestered with letters and requests for interviews. If the success of some project depended on the writing of a letter by an Academy official and that official was too busy to write it, Lavoisier would compose the letter and take it for signature; he was not easily baulked.

His official position at the Academy did not adversely affect his attendance at its meetings nor his participation in its routine duties. Half a dozen reports made during 1792 stand over his name, including reports on the respiration of insects, vegetable nutrition, and dyeing. But when he had attended to his Academy duties and those connected with the Weights and Measures Commission, the Advisory Board, and, till August, the Gunpowder Committee, he had no time left for private research.

Until 1792, the Academy as a body held aloof from the Revolution; political happenings were entirely outside its province. Some of its members, who belonged to the nobility, mainly those in the honorary class, had fled the country, but in spite of their absence business was carried on as usual. If, however, the Academy hoped, as it might reasonably expect to hope, to come peacefully through the turbulent times in which it now existed, it was doomed to disappointment. The first cloud that appeared was not apparently a very menacing one, but it proved to be the centre of an incipient depression, which, gradually increasing in intensity, finally caused the Academy to be engulfed.

It was Fourcroy who began the trouble. He was a man of some eminence as a chemist, but self-seeking and cowardly, as subsequent events abundantly proved. In April, 1792, he proposed at a meeting of the Academy that those members who had been, or who were suspected of being, guilty of that vague and comprehensive crime of incivism should be struck off the roll. He pointed out that the Society of Medicine had already done this, and thought that the Academy should follow its lead. This surprise proposal called forth protests from all sides; the Academy was not concerned with the political views of its members, and besides, who was to undertake the invidious task of deciding who was a loyal citizen and who was a counter-revolutionary? Anyone who had made an indiscreet remark might find himself branded as an enemy of the new Government. Fourcroy, no doubt expecting to gain popularity in Government circles, refused to withdraw his motion, but it was decided to postpone a decision on it till the next meeting.

The Academy was now in an awkward position, for if it definitely voted against the motion all would come under suspicion, while the passing of the motion would amount to an admission that membership of the Academy was confined to those who held certain political opinions. Since the matter had been raised, the latter alternative could hardly be avoided, but in order to dispense with a vote it was proposed at the next meeting to leave it to the Government to delete from the list of members any to whom they objected. This was rather an astute move, and a motion to this effect was carried in spite of Fourcroy's opposition. After some delay, presumably during which inquiries about the loyalty of members were made, the amended list was received by the Academy and, this danger safely negotiated, it expected to be left in peace since it had now gained what amounted to official recognition. All that it asked was to be left alone to pursue its investigations undistracted by controversies with which it as a body was not concerned.

But it was not to be. Towards the end of the year, when excitement was rising at the approaching trial of the King, the Academy began to be pointed at as a pre-Revolutionary institution, and since it was a relic of the old *régime* it was *ipso facto* suspect. The atmosphere became so hostile that it was decided to try to allay public suspicion by obtaining a testimonial from the National Convention. By arrangement, the members went in a body to the Convention and presented a report of their labours, specially emphasising the work of the Commission of Weights and Measures. The President of the Convention, in a laudatory speech, thanked the Academy for its loyalty and devotion, and the Convention ordered the report to be printed. Yet, so vacillating were the representatives of the people, that three days later, when the Academy asked to be allowed to fill the places rendered vacant by the deletion of the names of *émigrés* and suspects, permission was refused by the Convention. The Academy was in despair. Although it gave the Government every assistance in advising on any matter submitted to it, whether hospitals, war equipment, or banking, it could never retain public confidence for long.

The fact of the matter was that times were again stirring and excitement was again running high. The trial and execution of the King, which had horrified Europe, had been enthusiastically received by the French people, and in particular by the Parisians. Many now advocated the abolition of all institutions that had existed prior to the Revolution, and, while this drastic step did not commend itself to all, the proposal attracted suspicious attention to bodies like the Academy, whose mere existence, however innocuous, was considered to be, if not a positive scandal, at least a standing menace.

During all this time Lavoisier was unfailing in his devotion to the Academy and never lost an opportunity of defending its interests. He seemed to take a new lease of life in the fight which began for the very existence of the Academy. His part, too, in establishing the new system of weights and measures took him back to the joys of the laboratory. During the winter of 1792–3, in collaboration with Haüy, he was engaged in finding accurately the density of distilled water with a view to fixing the standard of weight. It is interesting to note in passing that the name first proposed (whether by Lavoisier or by another is not clear) for this standard was the *grave*. In May, 1793, he and Borda carried out experiments to find the comparative thermal expansion of copper and platinum in connection with the making of the standard metre. These apparently simple determinations involved much repetition and routine work in the effort to obtain a high degree of accuracy.

In the spring of 1793 relations between the Government and the Academy were becoming more and more strained. Lavoisier's letters applying for the usual Government grants were ignored, and he had recourse to the modern device of trying to get at the minister concerned through a member of the National Convention. He pointed out to this member that one of the possible results of the non-recognition and lack of support of science by the Government would be that

French scientists might be tempted to seek other lands in which they could carry on their labours in peace and dignity. It was therefore a patriotic duty on the part of the Convention to maintain the Academy. The matter was referred to the recently formed Committee of Public Instruction. A man called Lakanal was appointed by the Committee to investigate the claims of the Academy and report. To him Lavoisier wrote a long letter in which he indicated the various ways in which the Academy had assisted and could still assist the State. He recalled explicitly a number of matters on which the opinion of the Academy had been sought and the expert advice, which had cost the academicians time and labour, had cost the Government nothing. Was it fair to deny such men the means of subsistence? Some had already been compelled to leave Paris because they could not afford to live there.

For the Academy the choice of Lakanal was fortunate. He lent a ready ear to Lavoisier's arguments and immediately espoused the cause of science. His first victory was to obtain permission for the Academy to proceed with the election of members to take the places of those whose names had been expunged from the roll. A week later, as a result of his persistent advocacy, the grants to the academicians were restored, the only condition being continuous residence for six months within the territory of the Republic. The Academy had now gained its ends and settled down again to its usual routine. Lavoisier, not without reason, congratulated himself on the results of his pertinacity, and hastened to render the necessary claims enclosing certificates of residence. Alas for his hopes! His joy was short-lived. Delays caused by unsympathetic officials gave the Convention time to recant what, under the influence of Lakanal's persuasion, it had granted. There was a recurrence of hostility which, in July, evoked two further letters from Lavoisier to Lakanal. He renewed his appeal on patriotic grounds—that the prosperity of the country depended on the Academy which served as a consultative body for manufacturers, agriculturists, and the Government itself. He appealed for the continuance of the Academy on purely scientific grounds; it had published about 150 volumes of proceedings besides many books by individual members. The meetings of the Academy, he said, were "a sort of crucible wherein experiments, observations, and discoveries are submitted to a serious test." Finally, he reminded the Convention that there were several committees at work, of which the Weights and Measures Commission was the most important, whose abolition would at least check the development of some of the Convention's own schemes.

These letters had temporarily the desired effect; the Academy was again in favour. On August 1st, in the course of a discussion on the introduction of the proposed new weights and measures, the Academy was congratulated on its work, and its advice was sought on the names to be given to the new coins. Yet, a week later, the pendulum had swung again, and the Academy was involved in a general decree suppressing all learned societies. Surely there never was such a chapter of vacillation and inconsistency in the history of the government of a civilised nation. The fall of the Academy may have been a relatively small matter in those times when the destiny of a whole race hung in the balance, but its treatment at the hands of the people's representatives was symptomatic. The Convention feared what they could not understand. When Lavoisier, with Lakanal as mouthpiece, proved that it was to the country's advantage to preserve the Academy, the members of the Convention nodded sage heads in approval; when a member recalled the fact that the Academy was a royal institution which had harboured many of the hated aristocracy, they began to look askance at it. This inconsistency was born of suspicion, and was nurtured on fear. To what lengths suspicion and fear forced them is shown by the fate which befell many of the revolutionary leaders themselves and about 4,000 others during the Reign of Terror.

The suppression of all learned societies followed a report by the Committee of Public Instruction which, however, proposed that the Academy of Sciences should be provisionally exempted. The services of the Academy to the State and to science were enumerated in terms which showed that Lavoisier's letters had made not a little impression; to put it on no higher a plane, what the Committee really suggested was that the Republic could make good use of these savants. This ray of hope proved to be illusory. Members of the Convention who belonged to other societies were indignant that the Academy of Sciences should receive preferential treatment; " touch one touch all" was, in effect, their slogan. The upshot of it was that of the seven clauses in the Bill presented to the Convention by the Committee of Public Instruction only two were passed—that suppressing all learned societies and that transferring their functions to the Government.

Lavoisier's feelings may well be imagined. He had spared no effort to keep the Academy in being. The reasonableness and the justice of its claim to the active support of the Government had been countered by an unreasonable and unjust act. What more could the Academicians have done to prove their loyalty? What more could they have done to justify their corporate existence? Were any further steps now possible or was the decision of the deputies irrevocable? Many of Lavoisier's colleagues in the Academy were for peaceful submission to the will of the people as expressed by their representatives, but he who had constituted himself the active defender of the interests of science did not agree that weak submission was the correct policy. The facile manner in which the Convention could change its mind, hitherto a source of irritation, was now a source of hope, and Lavoisier determined to make yet another effort.

Although the Academy had not been officially notified of the decree of August 8th, it was decided at a session held two days later to make that the last meeting. A funereal depression hung over the assembled company of scientists, which was relieved only by the eagerness of many present to have their latest work adopted in order that it might appear in the last volume of the official proceedings. Lavoisier, ever optimistic and energetic, brought a ray of light into the prevailing gloom by suggesting that, while the Academy as then constituted must perforce cease to exist, application should be made for its members to be allowed to meet as a club for the purpose of discussing scientific matters. After the meeting Lavoisier wrote again to Lakanal, who had proved himself to be a staunch friend of the Academy. The letter, if it had been intended for his personal perusal only, would have been superfluous, simply preaching to the converted; it was intended to supply him with fresh arguments to place before the Convention. He reiterated that the work of the Academy, much of it of public utility, was now arrested; in particular, the work of the Weights and Measures Commission, which was now well advanced and on which a good deal of money had been spent (about 150,000 livres), would go for naught. The work need not be interrupted, and yet the letter of the law could be observed by the formation of a *Free and Popular Society for the Advancement of Science*. The grants previously made to the Academy could be transferred to this society, and it could be placed under the general supervision of a committee of the Convention.

Finally, he again appealed on behalf of those academicians whose very lives were jeopardised by the demise of the Academy. "I need hardly add, citizens, that the maintenance of the emoluments of those who have received them is only bare justice; there is not an academician who, if he had applied his intelligence and his means to other objects, would not have secured a livelihood and a good position in society. Relying on the public keeping faith with them, they have followed a career honourable certainly, but hardly lucrative. Several are octogenarians and infirm; several have drained their energies and impaired their health by work undertaken gratuitously for the Government; French loyalty will not allow the nation to disappoint their hopes, and they have at least a strict right to the pensions granted to all public officials. Citizens, the matter is urgent; if you allow the savants who composed the late Academy of Sciences time to retire to the country to take up other positions in society, and to devote themselves to lucrative work, the organisation of the sciences will be destroyed and half a century will not suffice to resuscitate a generation of scientists. I beseech you, for the sake of national honour, for the sake of society, for the good opinion of foreign nations which are looking on, obtain a temporary measure which will prevent the destruction of the arts which would be the necessary sequel of the overthrow of science."

This eloquent appeal re-energised Lakanal, and he once more applied himself to the thankless task of converting a number of men who knew little, and cared less, about science to granting Lavoisier's request. It says a good deal for Lakanal that he espoused so willingly the cause of the Academy. There is little doubt that in doing so he took his political life in his hands, and at the very best it was not a cause that would win him any prestige among his fellow-deputies. On the other hand, some who ought naturally to have been the champions of science took no active part in the defence of the Academy. Such a one was Fourcroy.

He had been a member of the Academy and he had made many original contributions to science. He was now a deputy and a member of the Committee of Public Instruction. Yet there is no evidence that he exerted himself in the very slightest on behalf of the Academy. The sombre fact is that he was a time-server, a man with no loyalty to his friends when there was the least possibility of such friendship involving personal danger or inconvenience. Whether Lavoisier made any appeal to him we do not know, but it seems likely that since that occasion when Fourcroy had tried to get the Academy to delete from its list of members the names of those who had fled the country and those who were suspected of incivism, relations between him and his colleagues had been strained. In the struggle for the existence of the Academy, Fourcroy left others to do the fighting. Had victory gone to the scientists Fourcroy was just the kind of man who would have resumed his place among them with the air of one of the victors.

Lakanal's further efforts made as a result of Lavoisier's letter bore immediate fruit. On August 14th the Convention passed a decree to the effect that those scientists who were engaged on work of public utility should continue such work until further notice, and that they should continue to receive the same remuneration as formerly. This looked like a triumph for Lakanal and his cause. Lavoisier considered it as such and joyfully convened a meeting of the Academy to consider the new situation. On the Saturday following the Convention decree the members arrived at the Louvre, their usual meeting-place, but found that entrance was denied them; seals had been affixed to their rooms following the previous decree and the order had not been countermanded because, it seems, the Convention never intended that it should be; the Convention was not at all concerned about the Academy but only its own pet projects, such as the reform of the weights and measures. This is shown clearly by the fact that on August 20th Fourcroy, in "a letter of bureaucratic dryness," asked Lavoisier for particulars regarding the constitution of the Commission and for an account of their work to date. The Commission was now to be transferred from Academy to Government auspices.

In a final and forlorn attempt to restore the Academy to life Lavoisier asked Lakanal to let him have a copy of the decree of August 14th, but this, when he got it, was of no use to him, for the Committee of Public Instruction had acquired from the parent body the convenient habit of changing its mind. Although it took no steps to rescind its resolution in favour of the Academy, it ignored it and set up a new organisation to carry on the work of the Weights and Measures Commission. Most of the members of the previous Commission were re-elected, and Lavoisier was one of the number. He continued his functions as treasurer and, in fact, he was really the director of the work.

The Academy was no more. Lavoisier had fought a good fight, but the odds had been too great. Even his colleagues, some of whom had even more at stake than he had, had not given him all the assistance he might have expected, and Fourcroy especially, who carried weight in the councils of the new Government, could have done a great deal, both publicly and privately. Lavoisier's failure to attain his end was a great disappointment to him. His whole life had centred round the Academy since his admission to its precincts twenty-five years previously. He had never allowed his other activities to interfere with his attendance at its meetings ; he had played an outstanding part in its routine work ; most of his discoveries had been announced at its sessions and published in its proceedings, and he had found his most intimate friends among its members. Now there was a big gap in his life. After nearly two years of uphill propaganda work against prejudice the Academy had ceased to exist. In the hour of failure Lavoisier did not forget the magnificent part played by Lakanal. When he saw that there was no hope even of a reprieve for the Academy he wrote to the man who had proved such a staunch advocate of its claims, thanking him for his devotion to the cause of science. At the same time he intimated to him that the members had decided not to antagonise public opinion by meeting even informally as a club.

CHAPTER XIX

ARREST

We must now return and learn the fate of the *Ferme Générale*. It was only natural that this should be one of the first institutions to be attacked when the Revolution began, since much of the blame for the state of the country was, rightly or wrongly, laid at its door. The tax collector is not even now a popular individual, but if we knew or suspected that his strenuous efforts to extract from us the utmost farthing of our debt were dictated by a desire for personal enrichment we should part with our hard-earned money even more grudgingly than we do. The campaign against the *Ferme Générale* began with the meeting of the States General. From all quarters attacks began to be made by those who had suffered at the hands of the *Ferme's* agents, and even some of these same agents who had their own private grievances against their employers added their complaints to the general denunciation. As is so often the case in such matters, no distinction was drawn between those *fermiers* who had tried to do their duty in an honest an upright manner and those who had resorted to doubtful artifices in order to increase the profits of their office. All were condemned as extortionists and blood-suckers who had waxed rich on the miseries of the poor.

In the stream of vituperative pamphlets and newspaper articles that appeared in 1789 and 1790 one idea began to emerge, namely, that the *Ferme* had systematically defrauded the Treasury over a long period by making false returns of their profits. The public grasped this accusation as being not only something tangible and " incivistic," but as carrying its own condemnation and as implying the only punishment possible—restoration of the stolen millions. Credit is due to the National Assembly for not being stampeded into hasty action by this abusive campaign ; it was not until March, 1791, that they bowed to the storm and cancelled the *Ferme's* contract. They realised the impossibility of making *fermiers* disgorge their excessive and ill-gotten gains, assuming that they were excessive and ill-gotten, but they threw a sop to public opinion, and incidentally greatly complicated the business of winding up the company, by antedating the cancellation to July 1st, 1789. A committee of nine *fermiers* was appointed to examine the accounts and report to the National Assembly by January 1st, 1793. Lavoisier was not a member of this committee, and thus his connection with the *Ferme Générale* ceased.

The committee was faced with an enormous task, and with the best will in the world they could not have completed it within the specified time. Fortunately for them their default, as it would have been considered, was overlooked because at the end of the year the National Convention was fully occupied in determining the fate of the King. No further official action was taken till June, 1793. By this time some of the deputies began to suspect that the committee was purposely delaying its report in order to allow the *fermiers* time to adjust their private affairs and flee the country. A resolution was passed disbanding the committee, putting their books under seal, and confiscating their funds.

Lavoisier, for some unknown reason, was involved in this decision. In spite of the fact that he had nothing to do with the Liquidation Committee, his laboratory to which he had hitherto had access, in virtue of his membership of the Weights and Measures Commission, was put under seal. He protested, but the times were too dangerous to carry such a protest too far, and he submitted to the indignity. After the suppression of the Academy and the setting up of the new Commission under direct Government auspices, he was allowed to retrieve under supervision the apparatus and papers necessary for the work. Apparently he was not very methodical in the classification of his correspondence and manuscripts, for it was found that the required papers were mixed up with other documents, and this necessitated an examination of them all by representatives of the Revolutionary Committee. The position for Lavoisier was humiliating. Although he had not entered into the hurly-burly of politics nor made any spectacular display of his democratic principles, he had all along placed his talents as a scientist and a financier at the disposal of the Government, and now he was rewarded by being suspected—of what? Of nothing in particular, possibly of that vague and all-embracing crime—incivism. A number of letters from Black, Priestley and others in English, with which the examiners could not deal, were sent to the Committee of Public Safety, but no incriminating matter was discovered, either in these or in any of the other documents. " All that it (the laboratory) contains bears testimony to your civism and dispels suspicion of any kind." The seals were thereupon removed.

Having obtained this official certificate of loyalty, and being again allowed to use his laboratory, he resumed the direction of the work of the Weights and Measures Commission and his duties with the Advisory Board.

It had been an anxious time for him for, although he knew that no word or act of his could reasonably be regarded as disloyal, there was always the danger that an enemy would produce a forged document or discover a sentence among his papers which, by an evil twist, could be construed as treasonable. That he fully realised this danger is shown by the fact that when his papers were sent to the Committee of Public Safety for examination he insisted on sealing them with his own seal so that they could not be tampered with. Nobody was safe in those uncertain times. Even the leaders themselves, popular idols one day, found themselves on the way to the guillotine the next. Marat had been murdered in July, Danton during the reconstruction of the Committee of Public Safety in the same month had been superseded, and he was soon to be " removed " at the instance of his successor Robespierre, whose period of power was just beginning.

Meanwhile the Liquidation Committee of the

Ferme Générale had been disbanded, and the affairs of the *Ferme* had not been settled. The Convention suddenly awoke to the fact that this state of affairs was all to the advantage of the *Ferme* and to the disadvantage of the State, with the result that on July 24th the Committee was empowered to resume its interrupted labours and ordered to present a report by April 1st, 1794. Two days later, so little were the *fermiers* trusted by the people's representatives, the Convention appointed a kind of supervisory committee to audit the accounts. This new committee was composed entirely of former employees of the *Ferme*, and one member of it had actually been tried and convicted of embezzlement and falsification of the accounts of his department. What an opportunity he had, not only for revenge, but also for erasing the evidence of his guilt ! He had escaped from prison and now posed as a martyr who had been persecuted by his aristocratic employers.

This move did not unduly disturb the Liquidation Committee ; they began to realise that little if any of their worldly wealth would remain to them after the Examining Committee had worked its will on the accounts, but their confidence in their ability to prove to any unbiassed person that the transactions of the *Ferme* had been square and above-board led them into a sense of security from which they were soon rudely awakened. Exactly two months after the committee had resumed its task, the Convention gave voice to its impatience at the long delay in the settlement of the *Ferme's* affairs: "This is the hundredth time," said a deputy, " that we have heard about the accounts of the *fermiers généraux.* I demand that these bloodsuckers of the public be arrested and that if their accounts are not settled in a month the Convention hand them over to the rigours of the law." Not one member of the Convention had the courage to oppose this demand, although the less bigoted must have realised its injustice. The committee had been allowed about six months to set their house in order, and now they were threatened with arrest if the task was not accomplished in one. Yet more unreasonable was the demand of one deputy that if the Liquidation Committee would not obey instructions all those *fermiers* who had signed the last three contracts should be arrested immediately.

The danger that had always been lurking round the corner was again confronting Lavoisier. Apart from the incident of the summer when his laboratory had been placed under seal, he had been the subject of several unfounded attacks. One of them was contained in a letter sent to the Revolutionary Committee which wrongfully and maliciously alleged that he had been in communication with one of the *émigrés.* The situation which had now developed, however, was distinctly more dangerous than it had been before, for by this time the period known to history as the Reign of Terror had begun. Marie Antoinette had paid the penalty of her intriguing with her native country, and hardly a day passed but the scaffold claimed its victims. The almost inevitable sequel of imprisonment was death. Men therefore concentrated not on legal defence, but on avoiding arrest. Yet, so confident were the *fermiers* that their cause was just that when the Convention did yield to the demands of the extremists for immediate arrest of the people's oppressors, they were not for the most part unduly perturbed.

At the time the fateful decision was actually made by the Convention Lavoisier was attending a meeting of the Advisory Board, of which he had been elected president about a fortnight previously. His first idea was to avoid arrest at all costs, and a slight delay in the execution of the warrant on account of a wrong address gave him time to make temporary plans. He argued that the Convention, when it realised that he was included in the general order, must surely make an exception in his case because of the active part he was taking in the work of the Commission of Weights and Measures. The fact had only to be pointed out to the Convention to secure his exemption. With this idea in mind, and after hurriedly consulting some of his friends, he decided to go into temporary hiding. But where to hide? He bethought himself of an old caretaker at the Louvre, where the Academy used to hold its meetings. Evidently he had earned the respect of this old man, who readily agreed to run the risk of harbouring a wanted man.

The next day Lavoisier addressed the following letter to the Convention:

"Representatives of the People,

"Lavoisier of the late Academy of Sciences left the *Ferme* about three years ago. Called at that time to the post of Commissioner of the National Treasury, he contributed most to its organisation. He is now National Commissioner of Weights and Measures.

" It is well known that he has never concerned himself with the general affairs of the *Ferme* which were conducted by a small committee appointed by the Minister, and, moreover, his published works show that he had always been mainly occupied with science.

" He is not a member of the committee which was appointed in execution of the decrees for the winding up of the accounts of the *Ferme Générale ;* he cannot therefore be held responsible for the delay for which the committee is blamed ; hence he does not think that he can come under the law which orders that the *fermiers généraux* shall be put under arrest until the accounts are made up. Since there is a doubt, he begs the National Convention to let him know if its intention is that he should occupy himself with the accounts of the *Ferme Générale*, a task which he does not think should be his, or if he is to continue to carry out his duties on the Commission of Weights and Measures for which he has worked till now with zeal and, he dares to say, with some success.

" This 5th day of frimaire in the year II. of the French Republic one and indivisible.

" LAVOISIER."

He sent this letter to the Committee of Public Instruction. It was read at a meeting held the same evening. It was received in silence ; not a voice was raised on Lavoisier's behalf. The chairman was one of Lavoisier's friends and associates, Guyton de Morveau, but even he, whether from fear of possible consequences or from faithless indifference, did not say a word in support of his friend.

Disappointed in this direction, Lavoisier turned to the Committee of Public Safety as a last hope, forlorn it must have been, for here were none of his intimate friends from whom he might expect assistance in his hour of need. Next day he wrote a letter

"To the citizens, representatives of the people, composing the Committee of Public Safety of the National Convention.

"Citizen Representatives,

"Lavoisier of the late Academy of Sciences is charged by the decrees of the Convention to co-operate in the establishment of the new measures adopted by the National Convention.

"On the other hand, a decree just passed orders the *fermiers généraux* to be consigned to a house of detention to work at the making up of their accounts; he is ready to assist in this, but he thought he ought first to inquire as to which of these orders he is expected to obey.

"The Committee of Public Safety would reconcile the two decrees if it would provisionally order Lavoisier to remain at home in a state of arrest under the supervision of two of his republican brothers. He would observe that he has not been a *fermier générale* for three years and that his person and all his wealth guarantee his moral and physical responsibility.

"This 6th frimaire in the year II of the Republic, one and indivisible.

"LAVOISIER."

These two letters are rather disappointing efforts. They lack dignity; indeed, they are almost cringing. One cannot blame him for trying to find a legitimate excuse for staving off arrest, since everything tended to show that the consequences would be of the gravest, but one would have liked to see him taking up a more dignified attitude in face of the serious situation, one which would have omitted any misleading reference to his having left the *Ferme* three years previously when the Government cancelled the contract and he had to leave. The only excuse one can find for him is that the letters were written possibly hurriedly and certainly under mental strain.

Whether any attention was paid to his second letter or none we do not know. What is certain is that no exception was made in Lavoisier's case. Neither his services to the State nor his eminence as a scientist counted against the fact that he had been a member of the hated company of tax-gatherers. When he learned that this appeal had also been ignored, he realised that it was futile to remain in hiding any longer; he would merely postpone, but not evade, the fate of his brother financiers. Accordingly, after giving the committee two days in which to take any action, he gave himself up to the police and was imprisoned with a score or so of the others in Port Libre, which was formerly a convent called Port Royal, and which had been converted into a house of detention for the reception of suspects. The building still stands, and is now a maternity hospital.

CHAPTER XX

IN PRISON

It is probable that all except the most pessimistic of the incarcerated *fermiers* were not unduly depressed by the turn events had taken. They were honestly convinced that although there had been cases of harshness and oppression at the instance of some of their agents the company had, on the whole, carried out its work efficiently and with rectitude. In this view they were probably justified. It was the system and not the *Ferme* that was at fault. When therefore they found themselves confined in a building which had not been specially adapted to house prisoners, they at once, and somewhat light-heartedly, set about making themselves as comfortable as possible. The discipline seems to have been free and easy, and there were neither bolts on the doors nor bars on the windows. Guards were posted in the corridors and at the outer doors, but within certain wide limits the prisoners were left very much to their own devices. Other prisoners of the poorer classes were housed on the second floor and the more well-to-do on the first floor. It is rather remarkable that a Government which stood for equality and fraternity should allow class distinctions among its prisoners. It would have been more in accordance with its principles, and it would have lent a touch of ironical humour to the situation if they had ordained that each aristocrat was to share his cell with a lowly brother.

The building had a primitive system of central heating by means of stoves placed in the corridors, but there was one room which had a fire in it, and Lavoisier was fortunate enough to be allocated to this room along with his father-in-law, Paulz, who had been arrested on the same day as Lavoisier, and another of his colleagues called Deville. The comparative luxury of a fire, however, had its drawbacks, as he was soon to discover, for it attracted those of his friends who were less fortunate. The prisoners were allowed to meet one another freely as, of course, was necessary, since the purpose of their confinement was to get those complicated accounts in order. Lavoisier was not selfish enough to want to exclude his friends from what little comfort his cell had to offer, but even in captivity he desired not to remain idle. The accounts were no concern of his, so he resolved to occupy his time in writing his memoirs, and he made a beginning on the second day of his imprisonment. His intention was to write a comprehensive treatise on modern chemistry, which would include all his principal papers and also the work of others in so far as it had contributed to the chemical revolution. He drew out a scheme and considered that the work would extend to eight volumes. It is very evident that he did not at this period contemplate the possibility, the fatal issue of the present pass.

Meanwhile, what of those of his friends who still enjoyed their freedom? Were they taking any steps to secure his release? It is sad to have to record that they all "forsook him and fled," with the sole exception of his wife. Certainly the Advisory Board put on record the "esteem that all its members have always had for Citizen Lavoisier and the regret that they experience on learning that he is no longer able to take part in their deliberations." This very mild and formal declaration could not be held to compromise any of those present at the session at which it was passed, but equally could not do anything to remedy the state of affairs which was implicitly condemned. In fairness, however, it must be stated that the Board did take a further step later, but only after Lavoisier had requested it to do so.

The bearing of Madame Lavoisier in this crisis was altogether admirable. All the time her husband was in prison she spared no pains in an endeavour to obtain his release. She approached influential friends, she sought interviews with those in authority, and she did succeed in obtaining one concession, permission to visit her husband occasionally. The situation was a very anxious one and also, for her, a rather delicate one. Her father as well as her husband was in the greatest danger, and any effort in the direction of securing the release of the latter must at least not exclude the possibility of saving the former as well. While, therefore, she might make the most of Lavoisier's services to science and the State, such advocacy would not extricate her father from the law's clutches. It was probably for this reason that in the overtures she made her contention was that the *fermiers* were innocent of any crime. She approached influential people, not as a suppliant of favours, but as an advocate of justice. "You want the lives of the *fermiers généraux*," she exclaimed on one occasion, "because you want their money; if they perish, they will die innocent." A woman of spirit this, and no mistake, but it is doubtful if her courageous frankness did her cause any good; in fact, her attitude, even if justified by the facts of the case, was calculated to cause irritation and antipathy, especially as the men whom she approached were lately risen to power.

Lavoisier's chief anxiety during the first few weeks of his imprisonment was on behalf of his wife, on whom the strain was already having an effect. A characteristic letter, written to her on December 19th, reveals the tender relationship between them and his solicitude for her health. "You give yourself, sweetheart, a lot of trouble and much weariness of mind and body, and I cannot share it. Be careful lest you impair your health, that would be the greatest of misfortunes. I am getting on in years, my life has been a happy one as far back as I remember, you have contributed to it and you still contribute to it every day by the marks of affection that you show me; I shall at least leave behind me memories of respect and esteem. So my task is finished, but you may expect to have a long life before you, do not squander it. I thought I noticed yesterday that you were sad; why should you be since I am quite resigned and shall regard as won all that I shall not lose? However, we are not without hope of being reunited, and meantime your visits are to me a great pleasure."

Obviously, Lavoisier was under no illusions as to his possible fate; current events pointed only too clearly to the unlikelihood of his escaping where so many accused of minor crimes compared with his were being daily sent to the guillotine. And yet he had planned a work which he estimated would run to eight volumes! Was he preparing his wife for the worst, but himself hoping for the best?

As time went on and none of Lavoisier's former friends who was in a position to do so made any move on his behalf, Madame Lavoisier became very bitter against them. From her long association with her husband as assistant and amanuensis in the laboratory, she knew how he had used his influence when he had acquired fame to promote the interests of his friends, and now they in their turn, when they had the opportunity of trying to repay him, left him unconcernedly to sink or swim. Even apart from any idea of their repaying him for any material assistance he had given them, they had been his intimate friends and in some cases his collaborators, yet now in his hour of need not one would run the risk of incurring popular disfavour by espousing his cause. Certainly there was a risk, but what is friendship worth if it is not prepared to make sacrifices? It is hardly surprising that Madame Lavoisier, when her husband suffered the extreme penalty of the law, laid his death at the door of the savants.

It is interesting to speculate as to what would have happened had Priestley been a member of the National Convention at this time. He had actually been invited to become a deputy after the Birmingham riots had deprived him of house and church, but he had declined the honour mainly on account of his lack of proficiency in the language. Would he have intervened on Lavoisier's behalf? Although he had no love for Lavoisier's oxygen theory of combustion, one cannot imagine a man of Priestley's high principles remaining inactive while a fellow scientist was in danger. Whether such intervention would have affected the course of events is very doubtful; in fact, Priestley might well have been implicated himself.

It was not long before the various bodies on which Lavoisier had served began to feel the want of his advice and direction. In less than two months the Commission of Weights and Measures realised that he had been the man at the wheel and that their craft was missing his guiding hand. They appealed to the Committee of Public Safety purely on grounds of expedience to allow him to return to his duties in his capacity as commissioner. The only effect of this appeal was that Lavoisier and five others, including the president, who had signed the letter, were relieved of their duties. The Assignat and Coinage Committee were emphatic as to the necessity of his release: "Take any measures you consider convenient in regard to this citizen, but he must be allowed to work in his laboratory." This appeal was also unsuccessful.

Meanwhile Lavoisier's house in Rue de la Madeleine had been put under seal and his chateau at Fréchines was later treated similarly. The former, however, contained many of the instruments which had been used in connection with the work of the Weights and Measures Commission and which were necessary for the continuance of that work. When this fact was realised application was made to the Committee of Public Safety for permission to raise the seals in order to obtain these instruments. Two members of the Committee of Public Instruction were deputed to go to Lavoisier's house to obtain what was necessary, and instructions were given for Lavoisier to be present under a guard in order, presumably, that he might indicate the particular instruments that would be required by those who were to carry out the remainder of the work. Was it an ironical coincidence, or could it have been maliciously planned, that the two Government representatives who were appointed to supervise the raising of the seals were de Morveau and Fourcroy, two of Lavoisier's most intimate friends of pre-Revolution days? And how did they feel when confronted by their former distinguished colleague now in the humiliating position of prisoner? Unfortunately, the proceedings are not recorded. If one may hazard a guess, Lavoisier uttered no reproaches, and confined his remarks entirely to the business in hand; de Morveau was guiltily uncomfortable; but Fourcroy, whose real attitude to Lavoisier in the palmy days of the Academy had been that of jealous rival rather than professional friend, secretly exulted. It may be that we do Fourcroy an injustice; it is to be hoped that it is so.

A second time the seals were raised, this time on the application of Madame Lavoisier, who was at the time assisting her husband to prepare a new edition of his "Physical and Chemical Tracts," for which some of his laboratory notes were necessary.

Since their arrest the *fermiers* had been reduced to inactivity as far as the making of the report on the finances of the *Ferme* was concerned, because all their books were at the offices of the *Ferme.* It had early been recognised by the National Convention that no good purpose would be served by simply imprisoning these men, and the intervening month had been utilised in converting the *Ferme* offices into a prison. By December 24th the alterations had been made, and the *fermiers* were transferred to their new quarters, which however, while well adapted to the transaction of business, had decided deficiencies as a residence. The sleeping accommodation was totally inadequate, and some of the *fermiers* were obliged to sleep on the floor. But that was a comparatively small matter beside the fact that they could now proceed with the drawing up of their financial report at the completion of which, as many of them fondly imagined, they would regain their liberty. They worked ten hours a day, and in a month they had concluded their labours.

In the meantime the ex-employee of the *Ferme,* with his supervisory committee, had been examining the *Ferme's* affairs and had " discovered " certain irregularities. It is notorious that the same set of statistics can be used to obtain conclusions which are diametrically opposed to each other, and this is just what happened in the present instance. While the *fermiers* were using the contents of their ledgers to exculpate themselves, the Government Committee from the same source were making out a plausible case against the financiers. Although the charges against them were not communicated to them, the *fermiers* heard about them from their friends who were still permitted to visit them, and they decided to issue a statement in reply to the accusations. Lavoisier, who had taken no part in the drawing up of the financial report, was now persuaded to assist in countering the charges in which he was also involved. The chief of the charges were deliberate theft of money which ought to have gone to the National Treasury amounting to 130 millions of livres, the making of irregular payments, delay in sending remittances to the Treasury, taking up to 10 per cent. on their capital instead of 4 per cent., as the terms of their contract allowed, and finally, profiteering on the sale of tobacco by adding water to it.

Lavoisier, with the assistance of his colleagues, drew up to all the accusations a detailed reply which would seem to carry conviction. He maintained that there was no condition in the contract limiting the rate of interest which might be earned on the capital employed; all that the State demanded was a certain sum which was arrived at after a full discussion with the minister concerned. As for the charge of adulterating tobacco, he was in a position to give actual figures from the factory cost sheets showing that the amount of water added was not excessive. That water was added, he freely admitted, because it was necessary to allow for evaporation between the factory and the consumer. As a further argument he pointed out that if the *Ferme* had been anxious to profiteer they would not have rejected all the bad tobacco leaves that entered the factories, as they undoubtedly did. Finally, the price charged to the retailers was calculated not on the total weight of the tobacco, but on what it would weigh if dry.

This reply rather took the wind from the committee's sails, but not to be outdone, they seized on the admission that water had been added to the tobacco, and tried to make people believe that this practice was "dangerous to the health of the consumer." That such a puerile charge should receive any credence gives some indication of the state of mind of the French people at this time. They did not seem to see that the mere bringing of such a charge was almost an admission that the rest of the case was weak, and, as it turned out, it became one of the principal items in the indictment of the *fermiers*. It was a point that the average man could understand, and the Yellow Press of the day made the most of it. It may be mentioned here that the other accusations brought against the financiers were later proved to have been absolutely unfounded; indeed, a later Government Committee showed that the State actually owed the *fermiers* money.

In spite of the fierce abuse to which the *fermiers* were subjected, both in the Convention and outside as a result of the reports of the supervisory committee, many of them continued to be optimistic as to the outcome of it all, but as time went on and the hope of freedom became more and more remote they began to see that they might, after all, have to make a fight, not only for their liberty, but for their very lives. Lavoisier, who had occupied his time with his chemical memoirs, began about the middle of April, 1794, to prepare his defence for the trial, which now seemed to be inevitable. The Reign of Terror was now at its height; the guillotine knife flashed, not daily, but many times a day, and its victims were in many cases condemned for offences of a much less serious nature than profiteering on tobacco and robbing the Government. It behoved the *fermiers*, therefore, to get up the best defence possible so that, should they be brought to trial, they might be able to present a case strong enough to impress even that most casual and perfunctory judicial body, the Revolutionary Tribunal.

Lavoisier's general plan was to collect a number of testimonials from those bodies which carried weight in Government circles. First he applied to the Advisory Board, asking for a certificate setting forth the work he had done both for science and for the Board. He suggested that if the idea of their giving a certificate did not appeal to them, they might draw up a report on his work. The Board acceded to his request and appointed a small committee to deal with the matter, which it did with commendable promptness. The report, which was adopted by the Board, was as follows:

"The Advisory Board of Arts and Crafts, after having heard the report of its committee on the work of Citizen Lavoisier drawn up at his request, considering the number and the importance of the discoveries of this citizen, the great and useful revolution which they have effected in chemistry, the flood of light which they have shed on the nature of many substances little known before our time and on the chief phenomena of vegetation and animal economy, the advantages which have resulted from them for nearly all the arts which have any connection with chemistry such as painting, assaying, and the working of mines, etc., and finally, the commendation of the majority of European scientists gives Citizen Lavoisier a distinguished place among the men who have brought honour to France. Considering again that Citizen Lavoisier has shared with zeal and assiduity the work of the Advisory Board in ensuring to inventors the rewards due to their skill it has been agreed that this testimony of its esteem shall be recorded in its minutes and that an extract shall be sent to Citizen Lavoisier." Rather an involved and not a very enthusiastic testimonial.

Lavoisier approached also his former colleagues of the Gunpowder Committee and two of his intimate Academy friends, Cadet and Beaumé, all of whom consented to put in writing their high opinion of him.

Finally, he drew up an autobiographical statement in which, without any attempt to exaggerate the part he had played in either the chemical or the political revolution, he set down the facts, and an imposing list of work and achievements they made. This done, he was now ready at a moment's notice to defend himself if the worst came to the worst.

Meanwhile, the time spent in prison had been by no means wasted. Certainly any original work was out of the question, but he had proceeded steadily with the writing of his ambitious work which he had provisionally entitled "Memoirs of Chemistry." By the end of April, so great had been his industry, the first two volumes were ready for the printer. Assisted by Séguin, he corrected the proofs of these volumes, and at the time of his death the printing of them was nearly complete. It speaks volumes for Lavoisier's temperament that during his last days, when the issue was no longer in doubt, he could concentrate on the exacting task of writing and proof-reading.

CHAPTER XXI

THE GUILLOTINE

TOWARDS the end of April, even those of the *fermiers* who had persisted in their hopeful view of their ultimate fate began to show signs of anxiety; their bearing became less confident and they were now more inclined to discuss seriously the possibility of their not escaping with their lives. Their wealth they had long given up hope of retaining. Lavoisier had on one occasion remarked that in the unlikely event of his regaining his freedom he would be a poor man and would have to work to earn his living. He thought he would probably take up pharmacy as being a profession which was closely allied to the subject that was dearest to him.

On May 5th, 1794, any glimmer of hope that remained to the *fermiers* was all but extinguished by a new decree passed that day by the National Convention, ordering them to be brought for trial before the Revolutionary Tribunal. Dupin, one of the men who had rapidly risen to power in those days of ever-changing leadership, and one of the most active opponents of the *Ferme Générale*, made a long statement to the Convention, in which he repeated all the charges that had been made against the former oppressors of the people, but suppressed for the most part the written replies that had been made to the accusations. And he now added a fresh accusation to the effect that the *Ferme* committee which had been appointed to render a report on the financial transactions of the *Ferme* had wilfully delayed completing that report in the hope that the former *régime* would be re-established. It is impossible to say whether there was any truth in this accusation, but in fairness he ought to have stated that part at least of the delay was due to the fact that for some months the committee was not allowed to proceed with the work because the National Convention had put their books and papers under seal. The case Dupin presented was such a strong one that no member of the Convention dared to say a word against it. His demand for the trial of the *fermiers généraux* was acceded to without discussion. While the decree may not exactly have been out of order, it really implied an extension of the functions of the Revolutionary Tribunal which, up till now, had dealt only with cases of incivism or counter-revolutionary activities. The alleged crimes of the *fermiers*, however, had been committed under the old *régime* and could not therefore have been directed against the Republic. But this was merely a technical point not worthy of consideration by those who were out to avenge the sufferings of the peasants at the hands of the infamous tax-gatherers.

The news of the new decree reached the temporary prison at the *Ferme* offices and the first to hear it was Lavoisier. To him it did not come altogether as a surprise; the influence on public opinion of the propagandist activities of their enemies had made it evident that the blow would fall sooner or later, and now that the crisis had come he and most of his companions faced it calmly and with the courage of wronged innocence. They immediately began to make preparations for the next episode, which would be their transference to one of the State prisons, by burning their personal papers and saying good-bye to their friends.

One or two of them, however, found their courage failing and began to think of a cowardly exit by way of suicide. The anxiety of the past five months which had been recently transformed into apprehension may have caused mental aberration ; or, is it possible that they were suffering from a guilty conscience ? Were they of the number who had abused their position or at least sanctioned the abuses which had undoubtedly existed ? In any case, they did seriously contemplate ending their worries by taking opium, and they suggested to Lavoisier that he should join them in a death compact. He not only indignantly refused to do so, but he also succeeded in dissuading them from committing such a cowardly act. He argued that there was no disgrace in being put to death unjustly, and that to commit suicide would amount to a confession of guilt and would absolve their enemies from the crime they were apparently about to perpetrate.

The transfer to the Concièrgerie took place the same evening. Legal formalities, notoriously slow and irksome, can be disposed of with undignified celerity when the officials choose to do so for their own ends. In this case the act of accusation, a necessary preliminary to imprisonment and a fairly long document, seems to have been drawn up and signed by the magistrate even before the decree had been passed by the Convention, so that it could be put into effect at once. The same evening, escorted by mounted police and torch-bearers, the thirty-two *fermiers* were taken from their temporary place of detention at the *Ferme* offices to the Concièrgerie, that notorious State prison which has been significantly described as "the ante-chamber to the scaffold." Some were consigned to the dungeons, which were filthy, verminous, and ill-ventilated; the others spent the night only a little less miserably in the cell which had been occupied by Marie Antoinette previous to her execution. The prison was shamefully overcrowded. Many had to sleep on the floor or on benches, and their only hope of obtaining a greater degree of comfort during subsequent nights (if there would be any subsequent nights) was the "removal" of the occupants of such beds as there were.

The following day passed uneventfully, except for the intervention of a sympathiser who arranged for a supply of blankets and bedding to be provided and three rooms to be put at the disposal of the *fermiers*. The more elderly of them (there were nine men over sixty years of age, one being seventy-five) had suffered severely from the cold and the general discomforts of their first night at the Concièrgerie, and they appreciated what they now realised were luxuries all the more for their experience of the lack of them.

The next day, May 7th, the preliminaries to the trial began. First all were searched, then they were interrogated individually. The interrogation was a mere formality, a kind of identification parade. During their return to their cells they were greatly exercised as to where their next meal was to come from. They had had to pay for their food, but their money had been confiscated during the search. However, an unknown benefactor, probably he who provided for their comfort at night, had ordered a good repast for them, and they never knew, nor is it known now, who was the Good Samaritan.

The trial might take place any day now, and in view of the unseemly haste with which matters had been pushed on during the last two days, most thought that it would be held the next day. They were a sad company during the remainder of that day, for their fate was almost a foregone conclusion. It may have been that night that Lavoisier wrote his last letter, a letter to his cousin.

" I have had," he wrote, " a fairly long career, and above all a happy one, and I believe that my memory will be accompanied by some regrets, perhaps by some glory. What more could I wish ? The events in which I am implicated will probably save me the inconvenience of old age. I shall die in good health which is yet another advantage that I must add to those I have enjoyed. If I experience any regretful thought it is that I have not done more for my family, that I am now stripped of everything and that I cannot give you any tokens of my affection and gratitude.

" It is only too true that the exercise of all the social virtues, of important services rendered to my country, a life usefully employed in the interests of the arts and human knowledge is not sufficient to preserve me from a dismal end and escape perishing as a guilty person.

"I write to you to-day, but to-morrow I should probably not be allowed to do so, and because it affords me some consolation to think of you and of those who are dear to me in these last moments. Remember me to those who are interested in me to whom this letter is in common. It is likely the last I shall write to you."

Here we have resignation to his fate tinged with justifiable resentment at his treatment at the hands of an ungrateful country, but it is significant that there is no mention of the desertion of his friends and colleagues either here or in any of his recorded words. Was he satisfied that any efforts they might have made in an attempt to save him would have been useless and simply resulted in inculpating themselves? Or did he scorn to make any comment on such friendship as deserts in the face of danger?

Dawn had hardly broken on the morning of May 8th when the prisoners were bundled out and again searched. This time everything was taken away from them; they were being prepared for the scaffold. Such proceedings, totally abhorrent to our modern sense of justice, were quite normal in those times aptly called the Terror. Robespierre, temporarily the idol of the people, had to get rid of the people's and his own enemies if he would retain his position. The people feared, above all, a return to the *status quo* *ante* revolution. Yet the forms of justice were for the most part retained. After the *fermiers* had been searched they were conducted to an ante-room of the court where they met the men, four in number, who were to conduct their defence, and a quarter of an hour was allowed for conference with the accused !

The trial began. The sessions of the Revolutionary Tribunal were held at the Palais de Justice in a large hall which rejoiced in the name of Salle de la Liberté. The accused were surrounded by police with fixed bayonets ; the jury was composed of tradesmen and artisans ; the president of the court was Coffinhal, a man, thirty-one years of age, of large stature and resounding voice, sallow complexion, black eyes and bushy eyebrows—truly one to inspire terror in the enemies of the Constitution ; he was assisted by two judges. The public prosecutor was there and the defending counsel, and, as a background to the whole scene, the general public was there in force to gloat over the plight of this bunch of aristocrats. And they did enjoy themselves. Right from the beginning the answers of the accused to questions put to them by the president were received with derisive laughter, and no attempt was made to check this unseemly behaviour. The atmosphere of the court was one of ribaldry instead of the gravity and solemnity due to the occasion. For an hour and a half questions, mainly of a formal nature, were put to the accused, then after a short adjournment the court got down to the real business of the day.

The public prosecutor opened his case by throwing a series of accusations at the prisoners. One of them was that the *fermiers* had sent false returns to the State regarding the profits of their contracts in order to obtain better terms for the next. When one of the *fermiers* replied that the price of each contract was fixed according to information supplied by Government offices and not by the *Ferme* offices, the president angrily interposed with the injunction that answers should be plain yes or no; in other words, they must not argue with the court; they might get the better of the argument and make the court look ridiculous.

The proceedings were here interrupted by the arrival of a message from the National Convention, which had passed only that morning a decree liberating three of the *fermiers généraux* who had been merely *adjoints* of the *Ferme* and had not signed any of the contracts. The relief of the three men concerned at being thus snatched from the edge of the axe can well be imagined, but their joy was tempered by thoughts of the plight of their friends with whom they had been so closely associated during the past months. As another of the *fermiers* had been set free two or three days before by the personal intervention of Robespierre, this left twenty-eight still before the Tribunal.

The public prosecutor went on with his case. After asking more questions, he made his speech in which he accused the prisoners of organised robbery of the State and of being "the authors of all the evils which for some time had afflicted France."

The case for the defence was then put, but with the best will in the world the counsel for the defendants could not in the circumstances have put forward a strong plea, since they had had no time for preparation. But had they the best will in the world? They dared not appear to support the accused too strongly; if they had done so they would probably have soon found themselves in the dock beside their clients. They brought forward what was at best mitigating circumstances such as the testimonial which the Advisory Board of Arts and Crafts had given Lavoisier, but this and other similar documents were held to be irrelevant. It was probably at this point in the proceedings that Coffinhal made his famous—or infamous—remark: "The Republic has no need of savants; justice must take its course." Justice! The defence, muzzled and inept, did not, indeed could not, make any impression on judge and jury, who had already made up their minds as to their verdict even before they had taken their seats that morning. But the outward forms of justice were gone through, a mere sham ritual which satisfied the ignorant that all was being done decently and in order, and satisfied the powers that were in their lust for revenge.

Next the summing-up. Coffinhal, himself a lawyer, realised that there was one weak point in the case for the prosecution, and that lay in the fact that the Revolutionary Tribunal had no legal power to deal with crimes committed before the Revolution. This, one might imagine, would be a quite insignificant detail in that travesty of a court of justice, but one must remember that in those fickle times the judge had to safeguard himself from possible action on the part of an enemy. His sending twenty-eight men to the guillotine when it was without his power to do so would, in proper hands, provide a useful lever with which to encompass his downfall. At any rate he was at considerable pains to have the charge in order, and the question which the jury had to answer was put by him in the following terms :

" Has there existed a conspiracy against the French people to favour by every means possible the enemies of France by exercising all kinds of exactions and extortions from the French people, by mixing with tobacco water and ingredients harmful to the health of the citizens, in taking 6 and 10 per cent. interest for the different securities and for the investment of funds necessary for the exploitation of the *Ferme Générale* while they were legally entitled to only 4 per cent., by retaining sums which should have been sent to the national Treasury, and by robbing the people and the national Treasury by every possible means to deprive the nation of immense sums necessary for the war against the despots arisen against the Republic and to hand them over to the latter ? "

There must be few cases in legal history where the judge, in his summing-up, has introduced a new charge against the accused. The fact that the alleged offences had been committed five, ten, fifteen years previously and that the war had begun only in 1794 did not affect the case. He had put the issue on a sound legal basis, he had safeguarded himself against possible recrimination, and he had ensured the conviction of the prisoners, though indeed the last had never been in doubt. The jury's verdict was unanimous: Guilty.

Did the jury answer Coffinhal's questions in detail? We do not know. Actually the verdict was never recorded. Time was passing; the tumbrils were waiting to convey the condemned men to the scaffold. Coffinhal hurriedly signed a blank sheet on which the verdict should have been recorded and passed on to the judgment of the court. "The verdict of the jury to the effect that it is established that there has existed a conspiracy against the French people tending to favour by every possible means the success of the enemies of France;

"That Clement Delaage, Danger Bagneus, Paulz, Lavoisier (and other twenty-four names) are all proved to be the authors or accomplices in the conspiracy;

"The tribunal, after having heard the public prosecutor on the legal aspect of the question, condemns the above-named to the penalty of death, according to Article 4 of the first section . . ." The article which sets forth the various kinds of treasonable acts was quoted in full. The judgment goes on:

"Declare the effects of the condemned confiscated by the Republic;

"Orders that at the suit of the public prosecutor the present judgment shall be carried out within twenty-four hours."

Followed scenes of enthusiasm among the spectators; revenge, and to some a vindictive revenge, is sweet. Exultant crowds followed the condemned prisoners to the Concièrgerie, where they were handed over to the executioner, Sanson. Bundled into the tumbrils, "biers of the living," they were slowly jolted through the streets to the accompaniment of a singing, dancing, shouting throng which crowded round the sombre procession to such an extent that the police had to force a passage at the sabre's point. Once during the journey the tumbrils were stopped at a certain corner in order to afford an opportunity to some privileged dwellers in the place to hurl insults and abuse at their victims. It was probably at this juncture that Papillon d'Auteroche made the famous remark: "What vexes me is to have such obnoxious heirs." On again, and so at last, still to the accompaniment of the *carmagnole*, the revolutionary song and dance, they reached the Place de la Revolution (now Place de la Concorde)—and the scaffold.

Here were no formalities; he whose name was first on the list was ordered to mount the steps; the knife fell, the severed corpse was removed, and the next on the list took his place. The third to be called was Madame Lavoisier's father, Paulz, now an old man of seventy-five. The fourth was Lavoisier.

Thus died Lavoisier in the prime of his manhood. Calmly he had faced his persecutors, calmly he had faced death. Sustained rather than embittered by the knowledge of his innocence, he had for some days ceased to make any attempt to fight against what he now realised was the inevitable. After Dupin's indictment in the National Convention, it was obvious that his and his colleagues' enemies were out for vengeance, not justice, and the farcical trial supplied ample confirmation of this. We have no record of

Lavoisier's bearing during the trial, but one can readily imagine that, though apparently calm and perhaps scornful, inwardly he would be seething with indignation at that travesty of justice. As to the conduct of the crowd during the progress of the prisoners through the streets, Lavoisier must have looked on with disgust and contempt. At the end his demeanour was serene and worthy of the great man that he was.

That one who had rendered so great service to science, to the State, and to humanity itself, one who had brought prestige to France by his universally acknowledged genius, one who was at the height of his powers and had reached the pinnacle of success, fame and triumph, one who had always sympathised with and laboured to improve the lot of the downtrodden should be condemned for treason was surely itself an act of treachery to which it would be difficult to find a parallel. It was indeed the " gravest crime of the Revolution." Although, like his contemporary, Cavendish, he had been free from financial worries all his life and was therefore saved from the distractions of teaching or preaching, which set a limit to Priestley's scientific work, he had consecrated his life to science and the State. Scientists, at first sceptical, later heaped honours on his head, but the State, although on many occasions giving voice to its appreciation, once more exemplified the shortness of public memory, and so a life favoured by fortune, lived in happy industry, and crowned with wonderful success, was cut short to the accompaniment of the plaudits of a Parisian rabble. Such are the fruits of revolution ! Such were the deeds perpetrated in the name of Liberty, Equality and Fraternity !

The funeral, as one would expect, was a crude, almost a revolting, ceremony. The bodies and heads were piled into baskets. The gruesome load was conveyed to the cemetery in the tumbrils which but an hour ago had borne the living to their doom. In the cemetery d'Errancis [1] a trench had been dug for the reception of that day's batch of victims, whoever they might happen to be. The cortège, accompanied only by the idly curious in lieu of mourners, stopped at the edge of the trench, and the severed bodies, after being stripped of their clothing, were tossed in unceremoniously. The only funeral oration was delivered the next day to an audience of one, and consisted of a single sentence: "It required but a moment for them to cut off his head, and perhaps a hundred years will not suffice to produce another like it." The speaker was Lagrange, and he was discussing the sad event of the previous day, and especially the loss of Lavoisier, with Delambre. Both had been members of the Academy of Sciences, and both had been Lavoisier's friends. How many more of his friends were that day condoling with one another at their personal loss as well as the loss sustained by science and indeed by France ? How many of them had guilty consciences in regard to the pusillanimous part they had played ? This we cannot know, but not so many months later, when the country had recovered a position of comparative stability, and when its citizens might give expression to their thoughts without fear of dire consequences following an indiscreet remark, Lavoisier's former friends were not slow to recall their friendship with him with pride. Even Fourcroy, despite his craven and despicable attitude during the dark days of the Revolution, afterwards blossomed forth as one of the great chemist's greatest admirers.

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[1] This cemetery has since been built over.

The death of Lavoisier and his colleagues was the subject of exultant comment in the French Press. In scientific circles in other European countries the news was received with horror and indignant protests were voiced. Any national jealousy that had existed was by common consent sunk in the universal condemnation of an act which robbed science of one of its most brilliant exponents. The loss to science by his untimely demise can never be estimated, but it is certain that if the success that had crowned his investigations on combustion had continued to attend him in the other regions which he intended to explore he would have anticipated many of the discoveries of the nineteenth century.

When the guillotine claimed Robespierre, a victim of his own drastic political methods, the Terror came to an end, and results achieved during the period could be ascertained. It was not long before it began to be realised that the balance was decidedly on the debit side, and the members of the administration who were responsible for this state of affairs began to be called in question. With the general results of the stocktaking we are not here concerned. When the accounts of the *Ferme Générale* came to be examined by a new committee, it was found that instead of the

Ferme owing the State some 130 millions of livres, as the previous committee had, in its desire for revenge, reported, it was discovered that the State actually owed the *Ferme* about eight millions. Popular opinion, partly in revulsion from the horrors perpetrated in the name of justice and partly in view of revelations such as that just mentioned, began to veer round in favour of the late members of the *Ferme Générale*, so that within eighteen months of their tragic death it was possible for the *Lycée des Arts* to hold with impunity a special meeting at which a memorial lecture on Lavoisier was delivered by Lagrange and a bust of Lavoisier installed.

The *Lycée des Arts*, established in 1793, was proud to claim Lavoisier as one of its members, and a day or two before his death it had sent a deputation to visit him in the Concièrgerie in order to award him the highest honour it had in its power to bestow on him. Having even at the risk of drawing suspicion on itself honoured Lavoisier in life, it now honoured his memory by holding this memorial meeting. Less than a year later a second function was held in honour of " the immortal Lavoisier." This was on a more elaborate scale than the first, with suitable decorative effects and several speeches, one of them by Fourcroy ! This fair-weather friend, now that he was recognised as the foremost French chemist, could afford to be generous to one who had formerly occupied that position to the exclusion of himself.

CHAPTER XXII

EPILOGUE

MADAME LAVOISIER was naturally overcome with grief. Within the space of a few minutes she had lost father and husband, and she had not even the consolation of a family to whom she might devote her affection, for her marriage had been childless. Almost to the end she had retained the hope of being able to avert what, to her, would be not only a tragedy, but a scandalous injustice. It may be that her proud bearing and her insistent demand for justice, although fully justified by the facts of the case, was not the proper attitude to assume on grounds of expediency. Nevertheless, as has already been pointed out, her position was a delicate and a difficult one, in that any special efforts she might make to secure the liberty of her husband would not necessarily extricate her father.

And now she mourned both, and in their fellow victims she lost many friends; indeed, she was now nearly friendless. To make matters worse, her hours of grief were violated by official visits to her home in consequence of the confiscation by the Republic of Lavoisier's effects, of which inventories had to be made. But the crowning indignity was her arrest on June 14th. No doubt she had been giving utterance to her bitter thoughts against those who had been responsible for the outrageous proceedings which had culminated in the death of her dear ones, and criticism of the powers that were, even if hastily spoken in a moment of grief, was not to be tolerated. However, the Committee of General Security, by whose order she was imprisoned, decided, after making inquiries, that she could not be accused of any crime against the Republic, and after two months of durance she was again free.

Madame Lavoisier was now not only friendless but penniless as well. Her husband's and her father's goods had been confiscated, and a new order took from her an income of 2,000 livres which she had held in her own right. In her extremity, her servants, one of whom had been in her service for eighteen years, came to her aid, and for several months she lived on their earnings. Such devotion was all the more remarkable in those days of revolutionary ideas, when the national upheaval had made masters of slaves and when newly found authority was being used to further private vengeance. Madame Lavoisier did not give up the struggle under this new persecution; neither her sore bereavement nor the loss of her means of sustenance could suppress this woman of spirit. She began to agitate for the return both of her own money and also of the property of her father and her husband. In December a petition was presented to the National Convention on behalf of the widows and children of the late *fermiers*, but its request for the restoration of this property was refused. It was not till May, 1795, that the Convention, as a result of much propaganda on the part of sympathisers, changed its mind and did restore the confiscated property. That this could happen within a year of the execution of the *fermiers* is typical of the fluctuations of public opinion during the Revolution, and after the violent diatribes of the previous year one can hardly credit that a deputy should be permitted to refer to the *fermiers* as "unjustly condemned," and not be howled down as a counter-revolutionary.

Even the return of her worldly goods did not satisfy Madame Lavoisier. She saw that the fickle tide of public and official opinion was turning in favour of the deceased financiers, and she determined to push home this advantage. It was probably she who was responsible for the appearance of a pamphlet in July, 1795, in which Dupin was denounced for the part he had played in the vindictive pursuit of the *fermiers.* The pamphlet told the whole story, exposing the biassed nature of the report he made to the Convention which was the immediate cause of their arrest, and it ended by demanding that their deaths should be avenged. The pamphlet caused a great stir, and the Press called for an inquiry. In August Dupin was arrested, and he escaped the fate of those whom he had pursued with his venom only by the General Amnesty, which was declared in October.

It was not till April, 1796, that the Convention order restoring the effects of the deceased *fermiers* was carried out. As soon as Madame Lavoisier was again in a position of comparative affluence one of her first thoughts was for those who had stood by her in her time of poverty. Her servants did not lose by their faithfulness.

Now that she had secured official admission of the injustice of the condemnation of the *fermiers* she began to consider the possibility of publishing the two completed volumes of Lavoisier's projected work, " Memoirs of Chemistry." She invited Séguin, one of his collaborators, to write a preface, but because he refused to pillory Fourcroy, de Morveau and others for the desertion of their friend, preferring to leave the matter to their own consciences, she dispensed with his co-operation, and for the time being abandoned the idea of publication. A few years later, probably as a result of pressure from her friends, she wrote an introduction herself, and the volumes were published privately in 1806.

In the days before the Revolution Lavoisier's house had been a centre of social as well as scientific activity. When time had healed the ghastly wounds inflicted on Madame Lavoisier in 1794, and when she had regained her former status, most of the former frequenters who still survived began again to gravitate towards her house. It was a great tribute to her charm and personality that they did so. It is almost superfluous to remark that those who, being in a position to do so, had not lifted a finger to save her husband, dared not show their faces in her drawing-room. Had any such one had the temerity to cross the threshold of her home he would surely have regretted his action.

And new friends were made. A distinguished visitor to Paris was Count Rumford who, by his scientific researches, particularly in heat, had earned fame. Introduced to Madame Lavoisier, he soon became a popular member of her circle of friends and a frequent visitor at her house. Mutual admiration grew to affection, and he asked her hand in marriage. They were married in 1805, but it soon became apparent that in temperament they were quite incompatible, and after four years of quarrelling and unhappiness they agreed to separate.

Count Rumford died five years later, but Lady Rumford lived for yet another twenty-five years. She died suddenly on February 10th, 1836, at the age of seventy-eight.

It is very unfortunate that little outside the covers of scientific books remains to remind Parisians of one of their greatest men. Over his grave, which might have become a shrine to which admiring pilgrims resorted, has arisen one of the richest quarters of Paris ; the Arsenal, where he lived for sixteen years, was destroyed during the Communist rising of 1871 ; and his house in rue de la Madeleine is no longer in existence. The bulk of his apparatus, however, has been preserved and may be seen at the Conservatoire des Arts et Métiers, and the chateau at Fréchines still stands, while belated recognition came in 1900, when a statue of Lavoisier was erected behind the Church of La Madeleine not far from the spot where his house stood.

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The suggestion that Lavoisier's works should be collected and published was first made by Dumas in 1835. In 1846, the Government intimated to the Academy of Sciences that it was prepared to undertake this publication at public expense, and a committee was set up to make the necessary arrangements. The matter hung fire till 1861, when Dumas was officially asked to act as editor. The first four volumes appeared between the years 1863 and 1868, but Dumas, who was now getting old and was otherwise occupied, asked to be relieved of the task of completing the work. The final two volumes were edited by Grimaux, and appeared in 1892 in time for the celebration of the centenary of Lavoisier's death.

" Lavoisier, 1743–1794," *d'après sa correspondance, ses manuscrits, ses papiers de famille, et d'autres documents inédits. Par* Edouard Grimaux. Paris, 1888.

This is the only complete and reliable biography of Lavoisier, but it shows here and there signs of national prejudice. It is now out of print, but what is really an abridged edition of it has been published (Librairie Plon, Paris, 1928).

" Memoires de Chimie." This work, begun by Lavoisier when he was in prison, was published in its incomplete form in 1806. The first two volumes and part of the fourth were all that were ready at the time of his death. They contain some of his more important papers and several by Séguin.

"An Essay on Phlogiston" (Kirwan). The 1789 edition of this book contains the replies of Lavoisier and others to Kirwan's arguments and also some further observations of the author.

Numerous books published during last century contain references more or less extended to Lavoisier and his work. For example, Lalande, Fourcroy, Quénaud, Desessarts, Cuvier in the years immediately following his death wrote or delivered laudatory eulogies of his work. Among modern works dealing with Lavoisier the best known are probably Berthelot's "La Révolution Chimique" and Thorpe's "Antoine-Laurent Lavoisier" in his "Essays in Historical Chemistry," the latter being a very brief *résumé* of Grimaux's biography. In the same book, in an article entitled "Priestley, Cavendish, Lavoisier, and La Révolution Chimique," Thorpe criticises severely Lavoisier and Berthelot, the former for his attempts to appropriate the discoveries of others and the latter for trying to justify Lavoisier's actions.

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